Laboratory Environment Safety and Health Committee
Cryogenic Safety Subcommittee

MINUTES OF MEETING 03-10

November 21, 2003

FINAL

Committee Members Present
R. Alforque
M. Iarocci
S. Kane
E. Lessard (Chairperson)
M. Rehak
A. Sidi Yekhlef
R. Travis* (Secretary)
K. C. Wu
(* non-voting)

Committee Members Absent
W. Glenn
P. Kroon
P. Mortazavi

Visitors
J. Dodd
A. Fazzi
Y. Ju
P. Rehak

Agenda:

1. **Review of the Columbia – BNL LHe eBubble Cryostat at Bldg. 832**

Minutes of Meeting: Appended on pages 2 through 4.

ESH COMMITTEE MINUTES APPROVED:

_*Signature on File 12-17-03*________   ________________________________
E. Lessard   Date   **J. Tarpinian   Date**
LESHC Chairperson   **ESH&Q ALD**

Chairperson E. Lessard called the tenth meeting in 2003 of the Laboratory Environmental Safety and Health Committee (LESHC) to order on November 21, 2003 at 1:40 p.m.

1. **Review of the Columbia – BNL LHe eBubble Cryostat:** E. Lessard invited J. Dodd of Columbia University – Nevis Laboratories to present the Columbia – BNL Liquid Helium eBubble Chamber Cryostat[1].
   - 1.1. Mr. Dodd provided a brief overview of the Electron Bubble Chamber
     - 1.1.1. The experimental device consists of a 1.5 LHe double walled test chamber (Nevis/BNL) immersed in a LHe/LN2 cryostat (supplied by Janis).
     - 1.1.2. The test chamber may be filled with liquid neon in the future for neutrino experiments.
     - 1.1.3. The test chamber will operate down to ~ 2K.
     - 1.1.4. The test chamber design pressure is 10 atmospheres, however, operating pressure is limited to 30 psig by the relief valve.
     - 1.1.5. Ten high voltage feed throughs will energize a field cage within the test chamber.
     - 1.1.6. A photoelectric source is used for current pulsing. In the future, solid radioactive material may be used as an ion source.
     - 1.1.7. The cryostat contains a LHe and a LN2 reservoir, each about 40 liters. Relief valves (set at 4 psig) protect the LHe volume. The LN2 volume is vented to the atmosphere.
   - 1.2. With regard to any use of radioactive material as an ionizing source (See 1.1.6 above.), the LESHC cannot give permission to bring radioactive materials onto the BNL site.
   - 1.3. Prior to the merger with the LESHC, the BNL Cryogenic Safety Committee had reviewed the LHe eBubble Cryostat on May 1, 2003.
     - 1.3.1. The draft minutes from the 5/1/03 meeting[2] contained nine issues for resolution.
     - 1.3.2. In preparation for the 11/21/03 meeting, Nevis Laboratories provided a formal response to these action items[1].
     - 1.3.3. Each issue is listed in Section 1.4, followed by a synopsis of the related discussion.
   - 1.4. Action Items from the 1 May, 2003 CSC Review of Nevis/BNL eBubble Chamber:
     - 1.4.1. <u>The issue of the Three Open Ports on the LN2 Vessel.</u> – The proposal to add slitted rubber hose on each port is acceptable to the Committee with the proviso that this arrangement be indicated on the P& ID - **Complete**[3].
     - 1.4.2. <u>Check Vent-rate Scenarios Studied by Janis in Determining the Size of the Vendor-installed Relief Valves.</u>

[1] Mr. Dodd's presentation, these Minutes and the referenced documents herein are posted on the LESHC website: http://www.rhichome.bnl.gov/AGS/Accel/SND/laboratory_environemnt,_safety_and_health_committee.htm.)

[2] The final version of this document is posted on the LESHC website: http://www.rhichome.bnl.gov/AGS/Accel/SND/laboratory_environemnt,_safety_and_health_committee.htm.)

[3] This action was completed prior to the issuance of these minutes.

1.4.2.1. The Committee reviewed the Nevis response and found it acceptable.

1.4.2.2. The Committee noted that the ODH rating is "Unclassified" and that no postings or ODH training are required. The Experimental Safety Review Form (PO2003-083, dated 4/4/03)[1] should be revised by the Principal Investigators (J. Dodd and P. Rehak) to reflect this.

1.4.3. Prepare Test Plan (and Witnessing) for eBubble Chamber 200 psi Pressure Test and Test of Relief Valves.

1.4.3.1. The Committee reviewed the Nevis response and a 9/30/03 memo from Committee Member Steve Kane[1] and finds them acceptable.

1.4.3.2. Witnessing of the relief valve tests by BNL is required. This is a BNL Safety and Health Services Division (SHSD) action. Committee Secretary (R. Travis) volunteered to coordinate with SHSD – **Complete**[3].

1.4.4. Work With Physics ESR (Ron Gill) to Develop Plan/Procedures for Leaving the Cryostat Unattended.

1.4.4.1. Mr. Dodd stated that the dewars would not be left connected to the eBubble cryostat when it is unattended.

1.4.4.2. The draft minutes from the 5/1/03 CSC meeting also required written procedures to be produced and reviewed.

1.4.4.2.1. The draft procedures are available at: http://www.nevis.columbia.edu/~ebubble/review/revdocs.html. Committee Member M. Iarocci volunteered to perform a review for the Committee – **Complete**[2, 3].

1.4.4.2.2. In accordance with the Experimental Safety Review Form PO2003 –083 dated 4/4/03[1], training on these procedures is required for all users of the eBubble cryostat. Other BNL training, such as Hazcom, Electrical Safety, and Cryogenic Safety, is specified in the ESR Form.

1.4.4.2.3. The Physics Department Training Coordinator (M. Zarcone) is requested to develop (or revise) JTAs for the users and enter the training requirements into the Brookhaven Training Management Database – **Complete**[3].

1.4.5. Check Whether the Two Pumping Ports Connected to the Vapor Cooling Circuit are Vacuum Jacketed.

1.4.5.1. The ports are not jacketed. However, the intention is to pump through one port at a time, so in the worst case only one RV would be plugged.

1.4.5.2. The Committee accepts the response to Action Item # 5, with the understanding that the Principal Investigators (J. Dodd and P. Rehak) will inform the LESHC Chairman (E. Lessard) if the ports or the relief valves are continuously frosted.

1.4.6. Make a Complete P&ID Drawing for the Whole System. – The Committee determined that the drawing that was provided was not in a P&ID format. Committee member M. Iarocci volunteered to assist Nevis with this task – **Complete**[2, 3].

1.4.7. Determine the Pressure Rating for the Feedthroughs, and Provide a Detail of the Associated Welds. – The Committee reviewed and accepted the information that was provided.

1.4.8. Provide More Detail on the Welds of the eBubble Chamber, Including Providing a Complete Set of Drawings. - The Committee reviewed and accepted the information that was provided.

1.4.9. Determine whether the Janis cryostat is built to code. – There was much discussion about the BNL requirements for ASME code compliance for non-commercially supplied cryostats in general and for the Janis cryostat in particular. Several attendees believed that the Janis vessel was a standard commercial cryostat and therefore exempt from the BNL requirement for code compliance.

1.4.9.1. The Committee requested that Nevis provide a letter from Janis to certify that the cryostat satisfies the requirements of their proposal.

1.4.9.2. Committee Member S. Kane volunteered to verify that the Janis cryostat is a commercially available vessel. – **Complete**[3]

1.5. The following motion was crafted and approved by the Committee:

1.5.1. Motion No. 1 - Prior to performing eBubble Cryostat commissioning activities, the Principal Investigators must assure that the open items associated with 1.4.3, 1.4.4, 1.4.6 and 1.4.9 have been completed.

1.6. Several members of the Committee have not visited the facility. J. Dodd will contact R. Travis prior to the start of eBubble operation to coordinate a walk through.

1.7. The draft minutes of the May1, 2003 meeting were approved by the Committee Members (in attendance) who had attended this earlier meeting[2].

1.8. The BNL requirement for ASME Code compliance for non-commercial cryogenic equipment has generated much discussion amongst the Committee Members. This issue will be addressed in a future internal Committee meeting where sufficient preparatory and Committee time can be allocated to this issue.

2. The Meeting was adjourned at 3:25 p.m.

Action Items from 1 May, 2003 CSC Review of Nevis/BNL eBubble Chamber

1. The issue of the three open ports on the LN2 vessel
2. Check vent-rate scenarios studied by Janis in determining the size of the vendor-installed relief valves
3. Prepare test plan (and witnessing) for eBubble chamber 200 psi pressure test and test of relief valves
4. Work with Physics ESR (Ron Gill) to develop plan/procedures for leaving cryostat unattended
5. Check whether the two pumping ports connected to the vapor-cooling circuit are vacuum-jacketed
6. Make complete P&ID drawing for whole system
7. Determine pressure rating for the feedthroughs, and provide detail of the associated welds
8. Provide more detail on the welds of the eBubble chamber, including providing a complete set of drawings
9. Determine whether the Janis cryostat is built to code

Also included:

10. Copy of BNL Physics Department ESR Form and Approval

1. The issue of the three open ports on the LN2 vessel

We propose to add lengths of rubber or Teflon tube to the ports on the vessel, long enough to make "U-Turns" so that the open ends are pointing downwards (this is also recommended by the vendor, see Attachment 1). In addition, this will avoid foreign material dropping into the vessel.

Attachments:

1. Copy of 10 May, 2003 e-mail from cryostat vendor Janis.

Date: Sat, 10 May 2003 09:33:58 -0400
From: Munir Jirmanus <mjirmanus@janis.com>
To: 'Jeremy Dodd' <dodd@nevis.columbia.edu>
Subject: RE: Columbia/BNL 16CNDT cryostat

Dear Jeremy,

I will attempt to answer all your questions in the same order they appeared.

1. What venting scenarios were considered in determining the size (1/2") of the pressure relief valves on the cryostat?

The pressure relief valves are selected based on our practical knowledge developed over the years since our company was established (1961).

2. The LN2 reservoir has three open holes at the top, for filling and venting - is there a risk of back-flow of water vapor into the holes with associated ice build-up, and if so, what modifications can be made to prevent this?

The risk is minimal. You can prevent it by adding either "Bunsen" type valves (rubber tubes with a slit for venting and sealed with a stopper), simple rubber tubes long enough to make a U turn and end up pointing downwards, or more costly pressure relief valves (or one valve with the three exits joined together) added to the entrances. Typically this can be done using an O-ring compression seal against the outgoing tubes, soldered to a cap with the pressure relief valves threaded in position.

3. The vacuum vessel is designed to ASME code (though not stamped) - are the reservoirs also to code?

The reservoirs are not designed to ASME code because this would contradict the cryogenic requirements of this unit (thin-wall tubes to reduce the heat load into the two reservoirs). These reservoirs are not vacuum vessels, and they operate at atmospheric pressure or slightly (~2 psi) over. The innermost tube (0.75" OD x 0.0625" wall) is designed to operate at high pressure and is thus designed to code.

Best regards,

Munir

****
PS. Please acknowledge receipt of this email message to ensure the continuity of communications.
****

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-----Original Message-----

2. Check vent-rate scenarios studied by Janis in determining the size of the vendor-installed relief valves

Our June response to Richard Thomas is included below:

We have examined in detail the venting rates, and corresponding ODH risks, under a variety of operating conditions and failure modes of the cryostat. For the "worst-case" scenario of loss of vacuum in the vacuum vessel, we have calculated the expected mass flow (venting) rate from the LHe reservoir, the LHe chamber and the LN2 reservoir, compared to the mass flow rates through their respective relief valves.

Attachment 1 shows estimates of mass flow rate from the LHe reservoir (section 3.1), LHe chamber (section 3.2) and LN2 reservoir (section 3.3) when the vacuum is lost. Using the calculated thermal loads on these volumes, and the corresponding latent heats, allows us to estimate the mass flow rate in each case. These are compared to the mass flow rate through the associated relief valves on each volume, calculated using the relief valve specifications provided by the vendor (see Attachment 2). The data are summarized in the table below.

	Mass flow rate under loss of vacuum (kg/s)	Max. mass flow rate through relief valves (kg/s)
LHe reservoir	0.379	0.604
LHe chamber	0.037	1.007
LN2 reservoir	0.043	0.338

In each case, the mass flow rate under loss of vacuum is less than the vent capacity of the corresponding relief valves.

Also shown (see Attachment 3, bullet 1) is the response of the vendor to the question of the size/capacity of the cryostat relief valves.

Attachments:
1. Detailed ODH calculations for the cryostat.
2. Relief valve specification provided by vendor (Circleseal).
3. Copy of 10 May, 2003 e-mail from cryostat vendor Janis.

P.T.O.

Since June, we have had ongoing discussions with K.C. Wu of the Cryogenic Safety Committee in order to gain a more complete understanding of the relief valve question. During this dialog we learned that the relief valves on the helium reservoir were a Generant model, VRV-250BB-4, with the specifications shown in Attachment 4. The vendor confirmed that the helium reservoir should be able to withstand internal pressures up to 4 atmospheres (Attachment 5), and on the basis of this information, K.C. Wu approved the relief valves (see his e-mail, Attachment 6).

Attachments:

4. Helium reservoir relief valve specifications provided by vendor (Generant).
5. Copy of 9 October, 2003 e-mail from cryostat vendor Janis.
6. Copy of 30 October, 2003 e-mail from K.C. Wu.

Calculation of ODH classification for Nevis LHe e-Bubble Chamber Cryostat

Yonglin Ju

Nevis Laboratories, Columbia University, NY 10533

1. Physical parameters

Thermal properties of Helium and Nitrogen

$T0 := 300$ [K] $Pa := 760$ [mmHg] $\rho he0 := 0.1625$ [kg/m³] $\rho n20 := 1.156$ [kg/m³]

$T\_he := 4.2$ [K] $Pv := 1.013 \cdot 10^5$ [Pa] $\rho fv := 124.8$ [kg/m³] $\rho gv := 16.49$ [kg/m³]

$hfv := -5.7407 \cdot 10^3$ [J/kg] $hgv := 14.981 \cdot 10^3$ [J/kg] $hfgv := hgv - hfv$ $hfgv = 2.072 \cdot 10^4$ [J/kg]

$T\_n2 := 77.3$ $\rho fn := 806.804$ [kg/m³] $\rho gn := 4.623$ [kg/m³]

$hfn := -121.877 \cdot 10^3$ [J/kg] $hgn := 76.99 \cdot 10^3$ [J/kg] $hfgn := hgn - hfn$ $hfgn = 1.989 \cdot 10^5$ [J/kg]

$R0 := 296.929$ [J/kg.K]

A. LHe Dewar

$Vhe := 250$ [L] $tt1 := 0.01 \cdot \frac{Vhe}{24}$ $tt1 = 0.104$ [L/h] **[LHe dewar normal boil-off rate, 1%]**

B. LN2 Dewar

$Vn2 := 250$ [L] $tt2 := 0.015 \cdot \frac{Vn2}{24}$ $tt2 = 0.156$ [L/h] **[LN2 dewar normal boil-off rate, 1.5%]**

C. LHe Vessel

$Dr := 12 \cdot (25.4 \cdot 10^{-3})$ $Dr = 0.305$ [m] $Hr := 21.5 \cdot (25.4 \cdot 10^{-3})$ $Hr = 0.546$ [m] $Dz := 0.020$ [m]

$Dn := 5 \cdot (25.4 \cdot 10^{-3})$ $Dn = 0.127$ [m] $Hn := 20 \cdot (25.4 \cdot 10^{-3})$ $Hn = 0.508$ [m]

$A1 := \frac{\pi}{4} \cdot (Dr^2 - Dn^2)$ $A1 = 0.06$ [m²] $A3 := \pi \cdot Dn \cdot Hn$ $A3 = 0.203$ [m²]

$A2 := \frac{\pi}{4} \cdot (Dr^2 - Dz^2)$ $A2 = 0.073$ [m²] $A4 := \pi \cdot Dr \cdot Hr$ $A4 = 0.523$ [m²]

$Ar\_he := A1 + A3 + A4$ $\boxed{Ar\_he = 0.786}$ [m²] **[Cold surface of the LHe reservoir]**

$Vr1 := \frac{\pi}{4} \cdot (Dr^2 - Dz^2) \cdot Hr$ $Vr1 = 0.04$ [m³] $Vr1 \cdot 1000 = 39.675$ [L] **[Volume of LHe in LHe reservoir]**

$Vr2 := \frac{\pi}{4} \cdot (Dn^2 - Dz^2) \cdot Hn$ $Vr2 = 6.276 \cdot 10^{-3}$ [m³] $Vr2 \cdot 1000 = 6.276$ [L] **[Volume of LHe in neck space]**

$Vr\_he := (Vr1 + Vr2) \cdot 1000$ $\boxed{Vr\_he = 45.951}$ [L] **[Total volume of LHe in LHe reservoir]**

D. LN2 Vessel

$Dno := 14 \cdot (25.4 \cdot 10^{-3})$ $Dno = 0.356$ [m] $Dni := 6 \cdot (25.4 \cdot 10^{-3})$ $Dni = 0.152$ [m]

$Hnz := 20 \cdot (25.4 \cdot 10^{-3})$ $Hnz = 0.508$ [m] $Hfn := 10 \cdot (25.4 \cdot 10^{-3})$ $Hfn = 0.254$ [m]

$Dn1 := 13 \cdot (25.4 \cdot 10^{-3})$ $Dn1 = 0.33$ [m] $Dn2 := 11 \cdot (25.4 \cdot 10^{-3})$ $Dn2 = 0.279$ [m]

$Ar\_n2 := 2 \cdot \frac{\pi}{4} \cdot (Dno^2 - Dni^2) + \pi \cdot Dno \cdot Hnz + \pi \cdot Dni \cdot Hfn$ $\boxed{Ar\_n2 = 0.851}$ [m²] **[Cold surface of LN2 reservoir]**

$Vr\_n2 := \frac{\pi}{4} \cdot (Dno^2 - Dni^2) \cdot Hnz \cdot 1000$ $\boxed{Vr\_n2 = 41.185}$ [L] **[Volume of liquid in the LN2 reservoir]**

E. LHe e-Bubble Chamber

$Dv := 0.108$ [m] $Hv := 0.170$ [m] $Hfv := 0.105$ [m] **[Hight of LHe in e-bubble chamber]**

$Av1 := \frac{\pi}{4} \cdot Dv^2$ $Av1 = 9.161 \cdot 10^{-3}$ [m^2] $Av2 := \pi \cdot Dv \cdot Hv$ $Av2 = 0.058$ [m^2]

$Ae\_he := 2 \cdot Av1 + Av2$ $\boxed{Ae\_he = 0.076}$ [m^2] ***[Cold surface area of e-bubble chamber]***

$Vfv := \frac{\pi}{4} \cdot Dv^2 \cdot Hfv$ $Vfv = 9.619 \cdot 10^{-4}$ [m^3]

$Ve\_he := Vfv \cdot 1000$ $\boxed{Ve\_he = 0.962}$ [L] **[Volume of LHe in e-bubble chamber]**

2. Mass

2.1 Thermal Load if vacuum is lost:

We assume $\boxed{qt := 10^4}$ [W/m^2]

$Et\_he := qt \cdot Ar\_he$ $\boxed{Et\_he = 7.859 \cdot 10^3}$ [W]

$Et\_n2 := qt \cdot Ar\_n2$ $\boxed{Et\_n2 = 8.513 \cdot 10^3}$ [W]

$Ee\_he := qt \cdot Ae\_he$ $\boxed{Ee\_he = 760.014}$ [W]

2.2 Mass in LHe vessel:

LHe vessel:

$p := 1.013 \cdot 10^5$ [Pa] $T1 := 4.2\,K$ $\rho fv = 124.8$ [kg/m^3] $hfgv = 2.072 \cdot 10^4$ [J/kg]

$\rho gv = 16.49$ [kg/m^3]

LHe mass at 4.2K in LHe vessel:

$Mhe := \rho fv \cdot \frac{Vr\_he}{1000}$ $\boxed{Mhe = 5.735}$ [kg]

Saturated gas helium mass at 4.2K in LHe vessel:

$Mghe := \rho gv \cdot \frac{Vr\_he}{1000}$ $\boxed{Mghe = 0.758}$ [kg]

The total enthalpy increase of load LHe of 45 liters in phase change:

$Elg := Mhe \cdot hfgv$ $Elg = 1.188 \cdot 10^5$ [J]

2.3 Mass in e-Bubble Chamber:

LHe vessel:

$p := 1.013 \cdot 10^6$ [Pa] $T1 := 4.2\,K$ $\rho fve := 151.55$ [kg/m^3] $hfgv = 2.072 \cdot 10^4$ [J/kg]

$\rho gve := 40.45$ [kg/m^3]

LHe mass at 4.2K in LHe vessel:

$Mhee := \rho fve \cdot \frac{Ve\_he}{1000}$ $\boxed{Mhee = 0.146}$ [kg]

Saturated gas helium mass at 4.2K in LHe vessel:

$Mghee := \rho gve \cdot \frac{Ve\_he}{1000}$ $\boxed{Mghee = 0.039}$ [kg]

The total enthalpy increase of load LHe of 45 liters in phase change:

$Elge := Mhee \cdot hfgv$ $Elge = 3.021 \cdot 10^3$ [J]

2.4 Mass in LN2 vessel:

LN2 vessel:

$p := 1.013 \cdot 10^5$ [Pa] $T1 := 77.3\,K$ $\rho fn = 806.804$ [kg/m^3] $hfgn = 1.989 \cdot 10^5$ [J/kg]

$\rho gn = 4.623$ [kg/m^3]

LHe mass at 4.2K in LHe vessel:

$Mn2 := \rho fn \cdot \frac{Vr\_n2}{1000}$ $\boxed{Mn2 = 33.228}$ [kg]

Saturated gas nitrogen mass at 77.3K in LN2 vessel:

$Mgn2 := \rho gn \cdot \frac{Vr\_n2}{1000}$ $\boxed{Mgn2 = 0.19}$ [kg]

The total enthalpy increase of load LHe of 40 liters in phase change:

$Elg := Mn2 \cdot hfgn$ $Elg = 6.608 \cdot 10^6$ [J]

3. Mass flow rate and release time

3.1 Time and mass flow rate estimation for LHe: (reservoir)

$Et\_he = 7.859 \cdot 10^3$ [W] → estimated mass flow rate

$m\_he := \frac{Et\_he}{hfgv}$ $\boxed{m\_he = 0.379}$ [kg/s] $t\_he := \frac{Mhe}{m\_he}$ $t\_he = 15.12$ [s]

If: $Pb := 1.013 \cdot 10^5$ [Pa] $T := 10$ [K] $\Gamma := 0.9$ $\tau := 1.659$

$Po := 3 \cdot 10^5$ [Pa]

Mass flow rate estimation for relief valve:

$d1 := 0.01$ [m] $n1 := 2$ $Ar1 := \frac{\pi}{4} \cdot d1^2 \cdot n1$ $Ar1 = 1.571 \cdot 10^{-4}$ [m^2]

$moutr := \frac{\Gamma \cdot Ar1 \cdot Po}{\sqrt{\tau \cdot R0 \cdot T}}$ → estimated max. flow rate through relief valve

$moutr = 0.604$ [kg/s] > $m\_he = 0.379$ [kg/s] *

3.2 Time and mass flow rate estimation for LHe: (bubble chamber)

$Ee\_he = 760.014$ [W]

$me\_he := \frac{Ee\_he}{hfgv}$ $\boxed{me\_he = 0.037}$ [kg/s] $te\_he := \frac{Mhee}{me\_he}$ $te\_he = 3.975$ [s]

If: $Pb := 1.013 \cdot 10^5$ [Pa] $T := 10$ [K] $\Gamma := 0.9$ $\tau := 1.659$

$Po := 10 \cdot 10^5$ [Pa]

Mass flow rate estimation for relief valve:

$d1 := 0.01$ [m] $n1 := 1$ $Ar1 := \frac{\pi}{4} \cdot d1^2 \cdot n1$ $Ar1 = 7.854 \cdot 10^{-5}$ [m^2]

$moutr := \frac{\Gamma \cdot Ar1 \cdot Po}{\sqrt{\tau \cdot R0 \cdot T}}$

$moutr = 1.007$ [kg/s] > $me\_he = 0.037$ [kg/s] *

3.3 Time and mass flow rate estimation for LN2: (reservoir)

$Et\_n2 = 8.513 \cdot 10^3$ [W]

$m\_n2 := \frac{Et\_n2}{hfgn}$ $m\_n2 = 0.043$ [kg/s] $t\_n2 := \frac{Mn2}{m\_n2}$ $t\_n2 = 776.256$ [s]

If: $Pb := 1.013 \cdot 10^5$ [Pa] $T := 100$ [K] $\Gamma := 0.9$ $\tau := 1.659$ $R := 2807.6$ [J/kg.K]

$P := 3 \cdot 10^5$ [Pa]

Mass flow rate estimation for open tube:

$d2 := 0.75 \cdot 0.0254$ $\quad d2 = 0.019$ [m] $\quad n2 := 3$ $\quad Ar := \frac{\pi}{4} \cdot d2^2 \cdot n2$ $\quad Ar = 8.551 \cdot 10^{-4}$ [m2]

$moutr := \frac{\Gamma \cdot Ar \cdot P}{\sqrt{\tau \cdot R \cdot T}}$ $\quad moutr = 0.338$ [kg/s] > $m\_n2 = 0.043$ [kg/s]

4. ODH calculation with fan available

Data of the confined volumn and fan vent rate:

$V := 20 \cdot 15 \cdot 10$ $\quad V = 3 \cdot 10^3$ [m3] [The confined volumn]

$C1 := 0.0283$ [m3/CF] $\quad CC := \frac{0.0283}{60}$ $\quad CC = 4.717 \cdot 10^{-4}$ [m3/s] [Fan rate]

$Q := 300$ [SCFM] $\quad Q := Q \cdot CC$ [m3/s] $\quad \boxed{Q = 0.141}$ [m3/s] [The ventilation rate of the fan]

Case I. The normal operation of 250L LHe and 250L LN2 Dewars

The normal vaporization rate: 1% LHe /day and 1.5% LN2/day

$Rn1 := \frac{tt1}{1000 \cdot 3600}$ [m3/s] $\quad Rn1 = 2.894 \cdot 10^{-8}$ [m3/s]

$Rn2 := \frac{tt2}{1000 \cdot 3600}$ [m3/s] $\quad Rn2 = 4.34 \cdot 10^{-8}$ [m3/s]

$R11 := \frac{Rn1 \cdot \rho fv}{\rho he0}$ $\quad R11 = 2.222 \cdot 10^{-5}$ $\quad R12 := \frac{Rn2 \cdot \rho fn}{\rho n20}$ $\quad R12 = 3.029 \cdot 10^{-5}$

$R1 := R11 + R12$ $\quad R1 = 5.251 \cdot 10^{-5}$ [m3/s] < $Q = 0.141$ [m3/s] [The spill rate]

$t := \frac{250 + 250}{tt1 + tt2}$ $\quad t = 1.92 \cdot 10^3$ [hr] $\quad t \cdot 3600 = 6.912 \cdot 10^6$ [s] $\quad \frac{R1}{CC} = 0.111$

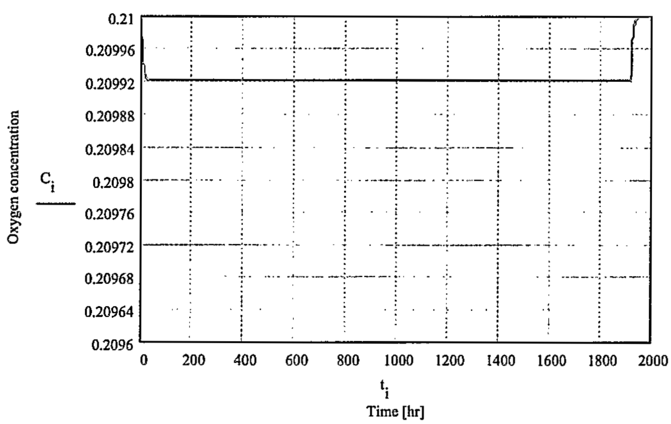
$i := 0 .. 3000$ $\quad t_i := i$

R1 < Q $\quad CI_i := 0.21 \cdot \left(1 - \frac{R1}{Q}\right) + \left[0.21 - 0.21 \cdot \left(1 - \frac{R1}{Q}\right)\right] \cdot e^{\frac{-Q}{V} \cdot t_i \cdot 3600}$ $\quad \boxed{CI_{1920} = 0.21}$

After the spill period (R=0)

$$Ce_i := 0.21 - \left(0.21 - CI_{1920}\right) \cdot e^{\frac{-Q \cdot \left(t_i - 1920\right) \cdot 3600}{V}}$$

$C_i := CI_i$ $\quad k := 0 .. 1080$ $\quad C_{k+1920} := Ce_{k+1920}$



The partial pressure:

$$PO2_i := C_i \cdot Pa$$

The fatality factor: $G_i := 10^{\left(6.5 - \frac{PO2_i}{10}\right)}$

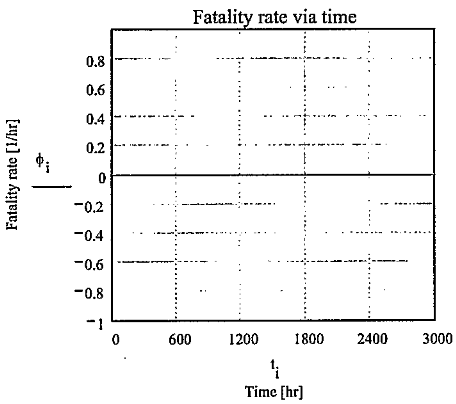
$$F_i := \mathrm{if}\left(G_i \geq 1, 1, \mathrm{if}\left(G_i < 1\cdot 10^{-7}, 0, G_i\right)\right) \qquad F_{1920} = 0$$

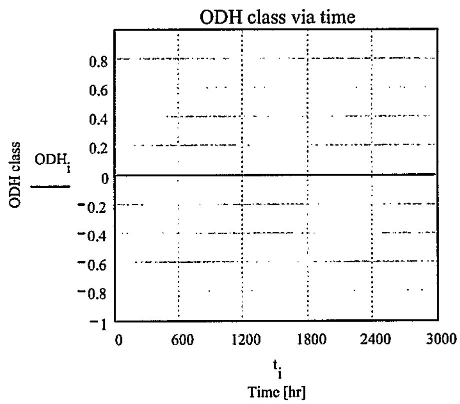
ODH fatality rate:

$$\boxed{\phi_i := \left(3\cdot 10^{-6} + 10^{-6}\right)\cdot F_i} \qquad \phi_{1920} = 0$$

ODH Classification:

$$\boxed{ODH_i := \mathrm{if}\left(\phi_i < 1\cdot 10^{-7}, 0, \mathrm{if}\left(\phi_i < 1\cdot 10^{-5}, 1, \mathrm{if}\left(\phi_i < 1\cdot 10^{-3}, 2, \mathrm{if}\left(\phi_i < 1\cdot 10^{-1}, 3, 4\right)\right)\right)\right)} \qquad time_i := t_i$$





Case 2. The normal operation of 45L LHe and 40 L LN2 vessel

The normal vaporization rate: 3 days

$$Rn1 := \frac{45}{1000\cdot 72\cdot 3600} \quad [m^3/s] \qquad Rn1 = 1.736\cdot 10^{-7} \quad [m^3/s]$$

$$Rn2 := \frac{40}{1000\cdot 72\cdot 3600} \quad [m^3/s] \qquad Rn2 = 1.543\cdot 10^{-7} \quad [m^3/s]$$

$$R11 := \frac{Rn1\cdot \rho fv}{\rho he0} \qquad R11 = 1.333\cdot 10^{-4} \qquad R12 := \frac{Rn2\cdot \rho fn}{\rho n20} \qquad R12 = 1.077\cdot 10^{-4}$$

$$R2 := R11 + R12 \qquad R2 = 2.41\cdot 10^{-4} \quad [m^3/s] \quad < \quad Q = 0.141 \quad [m^3/s] \qquad \frac{R2}{CC} = 0.511$$

$$t := 3\cdot 24 \qquad t = 72 \quad [hr] \qquad t\cdot 3600 = 2.592\cdot 10^{5} \quad [s]$$

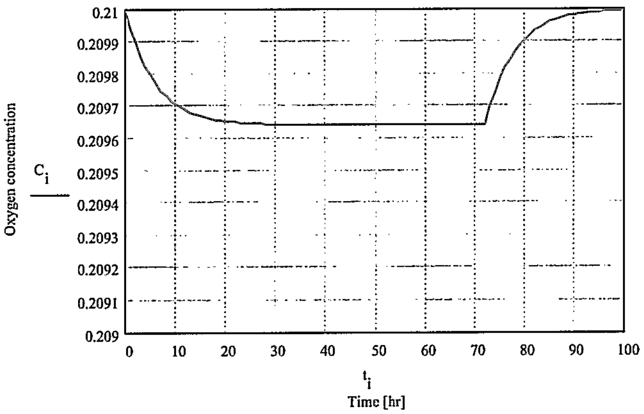
$$i := 0..\,100 \qquad t_i := i$$

R2 < Q $\quad C2_i := 0.21\cdot\left(1 - \frac{R2}{Q}\right) + \left[0.21 - 0.21\cdot\left(1 - \frac{R2}{Q}\right)\right]\cdot e^{\frac{-Q}{V}\cdot t_i\cdot 3600} \qquad \boxed{C2_{72} = 0.21}$

After the spill period (R=0)

$$Ce_i := 0.21 - \left(0.21 - C2_{72}\right)\cdot e^{\frac{-Q\cdot\left(t_i - 72\right)\cdot 3600}{V}}$$

$$C_i := C2_i \qquad k := 0..\,28 \qquad C_{k+72} := Ce_{k+72}$$



The partial pressure: $PO2_i := C_i \cdot Pa$

The fatality factor:

$$G_i := 10^{\left(6.5 - \frac{PO2_i}{10}\right)}$$

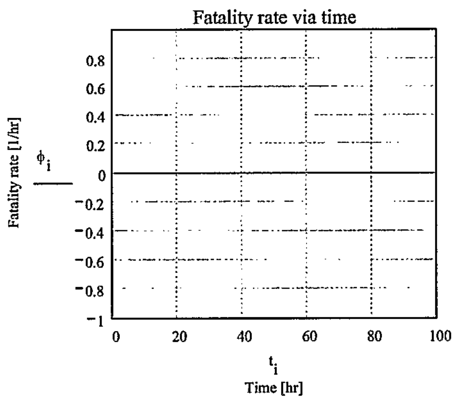
$$F_i := \text{if}\left(G_i \geq 1, 1, \text{if}\left(G_i < 1 \cdot 10^{-7}, 0, G_i\right)\right) \qquad F_{72} = 0$$

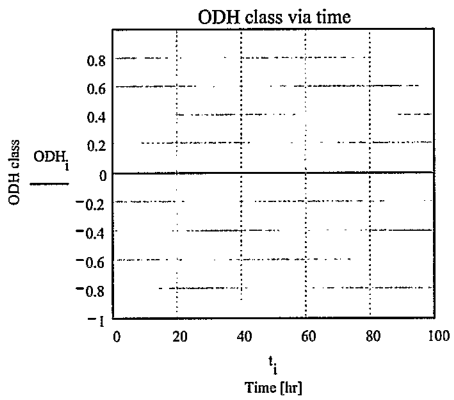
ODH fatality rate:

$$\phi_i := \left(3 \cdot 10^{-6} + 10^{-6}\right) \cdot F_i \qquad \phi_{72} = 0$$

ODH Classification:

$$ODH_i := \text{if}\left(\phi_i < 1 \cdot 10^{-7}, 0, \text{if}\left(\phi_i < 1 \cdot 10^{-5}, 1, \text{if}\left(\phi_i < 1 \cdot 10^{-3}, 2, \text{if}\left(\phi_i < 1 \cdot 10^{-1}, 3, 4\right)\right)\right)\right) \qquad time_i := t_i$$





Case 3. LHe vessel in EBC Cryostat broken, and the vacuum is lost

$m\_he = 0.379$ [kg/s] $\qquad t := \frac{Mhe}{m\_he} \qquad t = 15.12$ [s]

$R3 := \frac{m\_he}{phe0}$ [m³/s] $\qquad R3 = 2.334$ [m³/s] > $Q = 0.141$ [m³/s] $\qquad \frac{R3}{CC} = 4.948 \cdot 10^{3}$

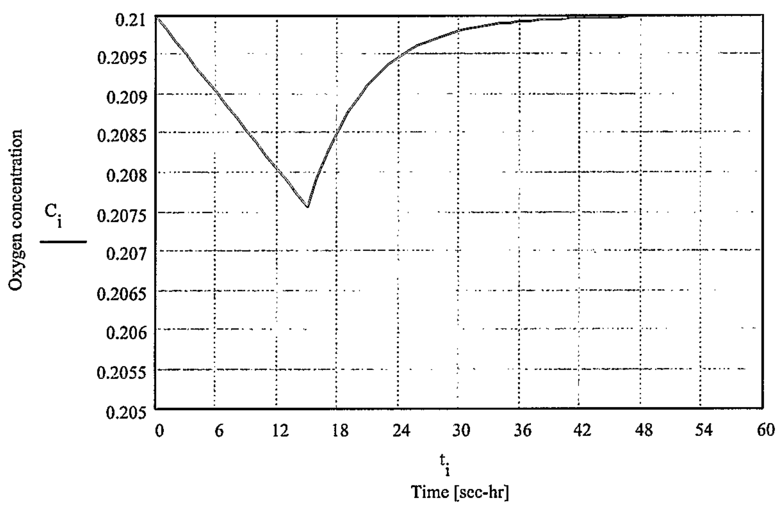
$i := 0..60 \qquad t_i := i$

R3 > Q $\qquad C3_i := 0.21 \cdot e^{\frac{-R3}{V} \cdot t_i}$ $\qquad \boxed{C3_{15} = 0.208}$

After the spill period (R=0)

$$Ce_i := 0.21 - \left(0.21 - C3_{15}\right) \cdot e^{\frac{-Q \cdot \left(t_i - 15\right) \cdot 3600}{V}}$$

$C_i := C3_i \qquad k := 0..45 \qquad C_{k+15} := Ce_{k+15}$



The partial pressure:

$PO2_i := C_i \cdot Pa$

The fatality factor:

$$G_i := 10^{\left(6.5 - \frac{PO2_i}{10}\right)}$$

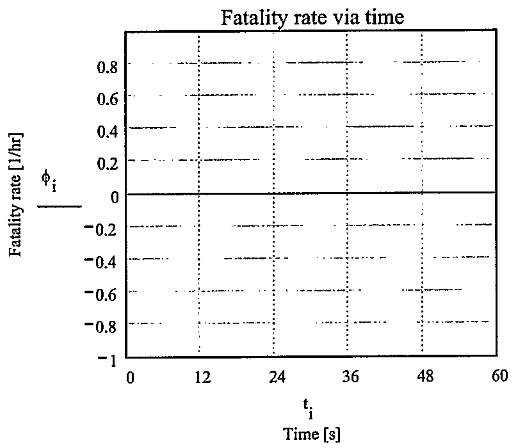
$F_i := \mathrm{if}\left(G_i \geq 1, 1, \mathrm{if}\left(G_i < 1 \cdot 10^{-7}, 0, G_i\right)\right) \qquad F_{15} = 0$

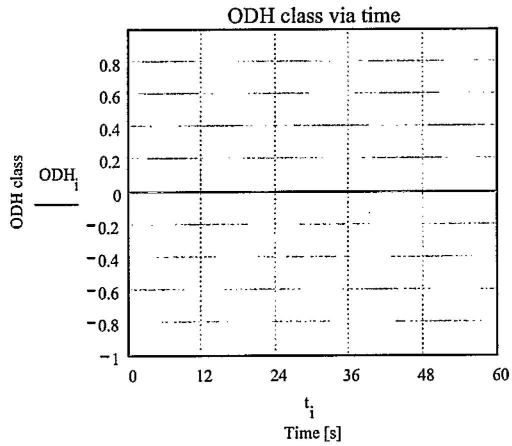
ODH fatality rate:

$\boxed{\phi_i := \left(3 \cdot 10^{-6} + 10^{-6}\right) \cdot F_i} \qquad \phi_{15} = 0$

ODH Classification:

$\boxed{ODH_i := \mathrm{if}\left(\phi_i < 1 \cdot 10^{-7}, 0, \mathrm{if}\left(\phi_i < 1 \cdot 10^{-5}, 1, \mathrm{if}\left(\phi_i < 1 \cdot 10^{-3}, 2, \mathrm{if}\left(\phi_i < 1 \cdot 10^{-1}, 3, 4\right)\right)\right)\right)} \qquad time_i := t_i$





Case 4. LN2 vessel in EBC Cryostat broken, and the vacuum is lost

$m\_n2 = 0.043$ [kg/s] $\qquad t := \frac{Mn2}{m\_n2}$ $\qquad t = 776.256$ [sec]

$R4 := \frac{m\_n2}{\rho n20}$ [m³/s] $\qquad R4 = 0.037$ [m³/s] $<$ $Q = 0.141$ [m³/s] $\qquad \frac{R4}{CC} = 78.507$

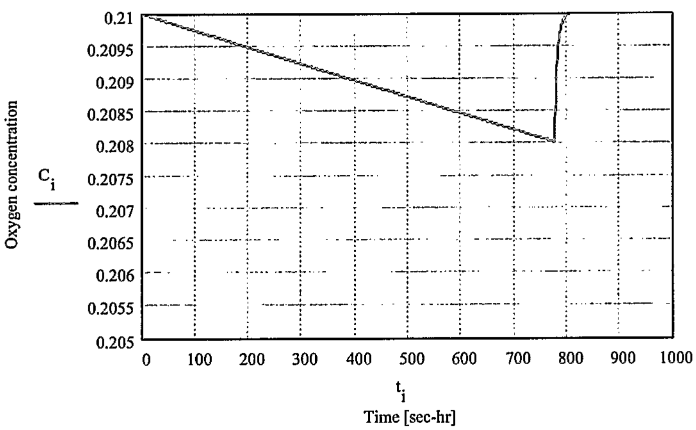
$i := 0..\ 1000 \qquad t_i := i$

R4 < Q $\qquad C4_i := 0.21\cdot\left(1-\frac{R4}{Q}\right)+\left[0.21-0.21\cdot\left(1-\frac{R4}{Q}\right)\right]\cdot e^{\frac{-Q}{V}\cdot t_i}$ $\qquad \boxed{C4_{776} = 0.208}$

The oxygen concentration after the spill period (R=0, Q=const)

$$Ce_i := 0.21-\left(0.21-C4_{776}\right)\cdot e^{\frac{-Q\cdot\left(t_i-776\right)\cdot 3600}{V}}$$

$C_i := C4_i \qquad k := 0..\ 224 \qquad C_{k+776} := Ce_{k+776}$



The partial pressure: $PO2_i := C_i \cdot Pa$

The fatality factor: $G_i := 10^{\left(6.5 - \frac{PO2_i}{10}\right)}$

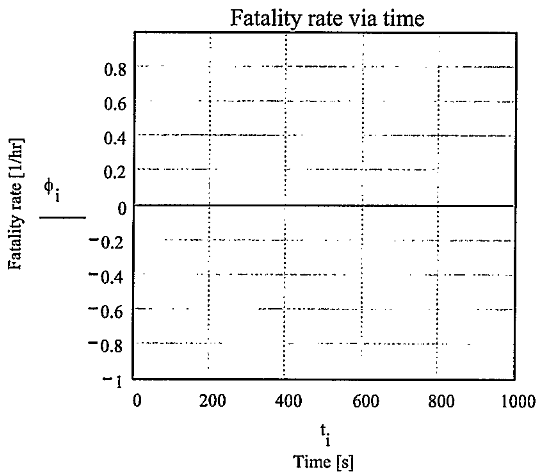
$F_i := \text{if}\left(G_i \geq 1, 1, \text{if}\left(G_i < 1 \cdot 10^{-7}, 0, G_i\right)\right)$ $F_{776} = 0$

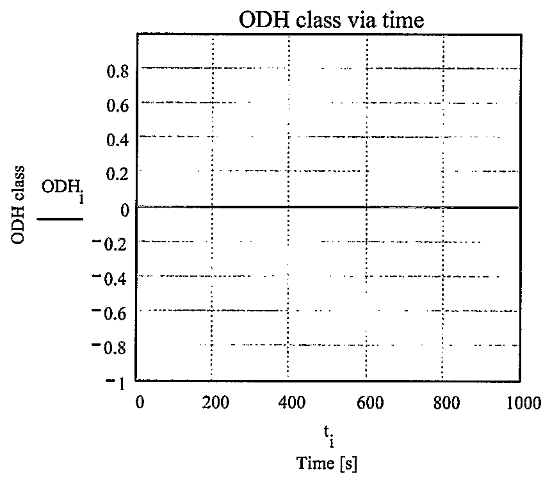
ODH fatality rate:

$\boxed{\phi_i := \left(3 \cdot 10^{-6} + 10^{-6}\right) \cdot F_i}$ $\phi_{776} = 0$

ODH Classification:

$\boxed{ODH_i := \text{if}\left(\phi_i < 1 \cdot 10^{-7}, 0, \text{if}\left(\phi_i < 1 \cdot 10^{-5}, 1, \text{if}\left(\phi_i < 1 \cdot 10^{-3}, 2, \text{if}\left(\phi_i < 1 \cdot 10^{-1}, 3, 4\right)\right)\right)\right)}$ $time_i := t_i$





Case 5. LHe e_bubble Chamber broken, and the vacuum is lost

$me\_he = 0.037$ [kg/s] $t := \frac{Mhee}{me\_he}$ $t = 3.975$ [s]

$R5 := \frac{me\_he}{\rho he0}$ [m³/s] $R5 = 0.226$ [m³/s] > $Q = 0.141$ [m³/s] $\frac{R5}{CC} = 478.528$

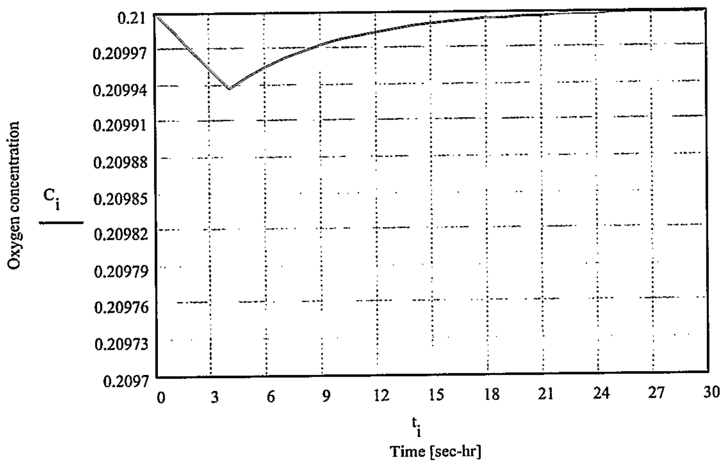
$i := 0..\ 30$ $t_i := i$

R5 > Q $C5_i := 0.21 \cdot e^{\frac{-R5}{V} \cdot t_i}$ $\boxed{C5_4 = 0.21}$

After the spill period (R=0)

$Ce_i := 0.21 - \left(0.21 - C5_4\right) \cdot e^{\frac{-Q \cdot \left(t_i - 4\right) \cdot 3600}{V}}$

$C_i := C5_i$ $k := 0..\ 26$ $C_{k+4} := Ce_{k+4}$



The partial pressure:

$$PO2_i := C_i \cdot Pa$$

The fatality factor:

$$G_i := 10^{\left(6.5 - \frac{PO2_i}{10}\right)}$$

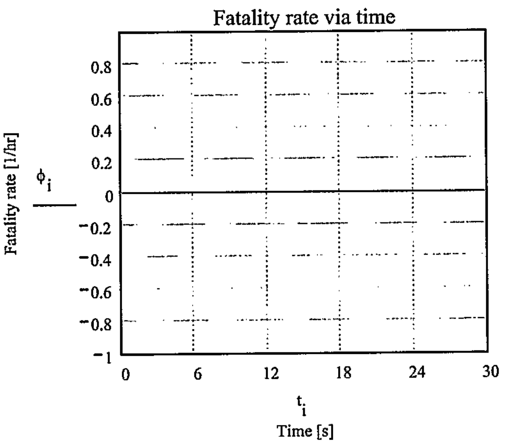
$$F_i := \mathrm{if}\left(G_i \geq 1, 1, \mathrm{if}\left(G_i < 1 \cdot 10^{-7}, 0, G_i\right)\right) \qquad F_5 = 0$$

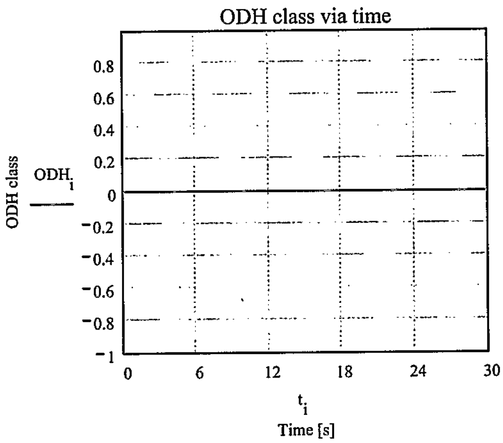
ODH fatality rate:

$$\phi_i := \left(3 \cdot 10^{-6} + 10^{-6}\right) \cdot F_i \qquad \phi_5 = 0$$

ODH Classification:

$$ODH_i := \mathrm{if}\left(\phi_i < 1 \cdot 10^{-7}, 0, \mathrm{if}\left(\phi_i < 1 \cdot 10^{-5}, 1, \mathrm{if}\left(\phi_i < 1 \cdot 10^{-3}, 2, \mathrm{if}\left(\phi_i < 1 \cdot 10^{-1}, 3, 4\right)\right)\right)\right) \qquad time_i := t_i$$





Conclusion

Fatality factor = $3*10^{-6}$
Fatality rate < 10^{-9}
ODH class = 0

Under the worst case condition, fatality rate is lower than 10^{-9} for Nevis e-Bubble Chamber Cryostat at Atlas Building. Therefore, ODH is unclassified according to "BNL ODH Risk Assessment".

CIRCLE SEAL CONTROLS

RELIEF VALVES
500 Series
Popoff, inline .5-150 PSI

MODEL NUMBER	O-RING MATERIAL	OPERATING TEMPERATURE	SUITABLE FOR
559 577	Buna N	-40° to +250°F	General Purpose, Air, Acetylene, Ammonia, Freon 12, Hydrogen, Inert Gases
532	Viton	-20° to +400°F	Aromatic Fuels, Synthetic Oils, Solvents, Carbon Tetrachloride, Toluene, Trichloroethylene, Steam
533	Neoprene	-40° to +250°F	Oxygen, Helium, Air, Hydrogen, Carbon Dioxide, Nitrogen, Acetylene
562	Ethylene Propylene	-65° to +300°F	Skydrol, Air, Steam
524	Silicone	-65° to +400°F	Air, Chlorinated Transformer Oil, Oxygen. Not available for cracking pressures above 74.9 PSI
520	Teflon	-100° to +400°F	Chemically inert. Suitable for nearly all fluids. Not available for cracking pressures below 2.5 PSI
K520T1	Teflon	-320° to +165°F	Especially assembled and LOX cleaned
580T1	Teflon	-320° to +165°F	No cryogenic processing

TECHNICAL DATA

MATERIAL.................Body and internal parts—bar stock

SPRING ....Stainless steel 302 or 17-7Ph

RESILIENT SEAL........ See service recommendations

OPERATING PRESSURE...0-200 PSI Satisfactory for vacuum applications

CRACKING PRESSURE....5-150 PSI Higher cracking pressures available—please check with factory. (Cracking pressure is defined as 5 cc/mi. with gas, except for 520 Series for which flow is 0.02 SCFM.) **NOTE:** See exceptions for Teflon and Silicone under Service Recommendations.

FOR INLINE VALVES:
PROOF PRESSURE ....400 PSI
BURST PRESSURE .. Above 500 PSI

ADJUSTMENT .... Adjustment is on inlet side, and cannot be tampered with after valve is installed.

†Alpha Code is for Circle Seal internal use only.

HOW TO ORDER

D 559 A-6MP-10

PART NUMBER DESIGNATION

VARIATION IDENTIFICATION
D— Prefixed Part Number is supplied with a cap which diverts high pressure blasts from personnel and instruments. Serves as a rain and dust shield. Increases flow capacity and facilitates manual override.
NOT RECOMMENDED FOR CRACKING PRESSURES BELOW 2 PSI
K—Cryogenic service (stainless steel valves only) (Specially manufactured, cleaned and tested for cryogenic temperatures)

BASIC MODEL NUMBER

MATERIAL
A—Aluminum T1—Stainless, 316
B—Brass

END CONNECTIONS—INLET/OUTLET
(size in 1/8")
M—Male pipe P—Female pipe

CRACKING PRESSURE—Specify setting in psi.

1M thru 2M & 2MP thru 3MP			3M thru 12M & 4MP thru 10MP		
CODE†	C.P. SETTING	C.P. RANGE	CODE†	C.P. SETTING	C.P. RANGE
A	0.5	.2-.9	A	1	.5-2.4
B	1	1.0-2.3	B	4	2.5-5.9
C	4	2.4-5.5	C	10	6.0-13.9
D	10	5.6-13.9	D	20	14.0-31.0
E	20	14.0-27.9	E	50	31.0-72.9
F	30	28.0-33.9	F	100	73.0-150.0
G	55	34.0-74.9			
H	90	75.0-104.9			
J	125	105.0-147.9			

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1111 WARDLOW CIRCLE
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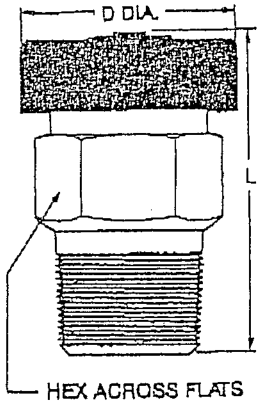
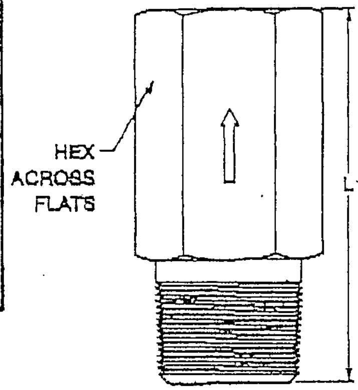


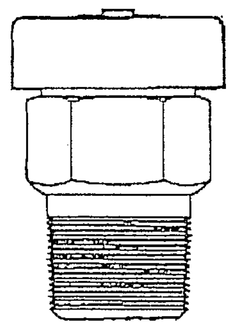
PIPE SIZE MALE	L	HEX	D DIA. MAX
1/8	1.14	1/2	.69
1/4	1.38	5/8	.90
3/8	1.43	3/4	1.21
1/2	1.88	1	1.45
3/4	2.31	1 1/4	1.45
1	3.16	1 1/2	1.89



PIPE SIZE MALE & FEMALE	L	HEX
1/4	1.62	3/4
3/8	2.08	7/8
1/2	2.34	1 1/8
3/4	2.72	1 1/4
1	3.62	1 1/2
1 1/4	4.67	1 7/8

*Complete part number must include cracking pressure. See chart on previous page.

			559	533	532	524
ALUMINUM	POPOFF	1/8	559A-1M-*	533A-1M-*	532A-1M-*	524A-1M-*
		1/4	559A-2M-*	533A-2M-*	532A-2M-*	524A-2M-*
		3/8	559A-3M-*	533A-3M-*	532A-3M-*	524A-3M-*
		1/2	559A-4M-*	533A-4M-*	532A-4M-*	524A-4M-*
		3/4	559A-6M-*	533A-6M-*	532A-6M-*	524A-6M-*
		1	559A-8M-*	533A-8M-*	532A-8M-*	524A-8M-*
	INLINE	1/4	559A-2MP-*	533A-2MP-*	532A-2MP-*	524A-2MP-*
BRASS	POPOFF	1/8	559B-1M-*	533B-1M-*	532B-1M-*	524B-1M-*
		1/4	559B-2M-*	533B-2M-*	532B-2M-*	524B-2M-*
		3/8	559B-3M-*	533B-3M-*	532B-3M-*	524B-3M-*
		1/2	559B-4M-*	533B-4M-*	532B-4M-*	524B-4M-*
		3/4	559B-6M-*	533B-6M-*	532B-6M-*	524B-6M-*
		1	559B-8M-*	533B-8M-*	532B-8M-*	524B-8M-*
	INLINE	1/4	559B-2MP-*	533B-2MP-*	532B-2MP-*	524B-2MP-*
		3/8	559B-3MP-*	533B-3MP-*	532B-3MP-*	524B-3MP-*
		1/2	559B-4MP-*	533B-4MP-*	532B-4MP-*	524B-4MP-*
		3/4	559B-6MP-*	533B-6MP-*	532B-6MP-*	524B-6MP-*
		1	559B-8MP-*	533B-8MP-*	532B-8MP-*	524B-8MP-*
		1 1/4	559B-10MP-*	533B-10MP-*	532B-10MP-*	524B-10MP-*
316 S.S.	POPOFF	1/8	559T1-1M-*	533T1-1M-*	532T1-1M-*	524T1-1M-*
		1/4	559T1-2M-*	533T1-2M-*	532T1-2M-*	524T1-2M-*
		3/8	559T1-3M-*	533T1-3M-*	532T1-3M-*	524T1-3M-*
		1/2	559T1-4M-*	533T1-4M-*	532T1-4M-*	524T1-4M-*
		3/4	559T1-6M-*	533T1-6M-*	532T1-6M-*	524T1-6M-*
		1	559T1-8M-*	533T1-8M-*	532T1-8M-*	524T1-8M-*
	INLINE	1/4	559T1-2MP-*	533T1-2MP-*	532T1-2MP-*	524T1-2MP-*
		1/2	559T1-4MP-*	533T1-4MP-*	532T1-4MP-*	524T1-4MP-*
		3/4	559T1-6MP-*	533T1-6MP-*	532T1-6MP-*	524T1-6MP-*



For ASME code valve, available in 1/4 inch size only. Add ASME after valve number. For operation details see ASME Valve catalog sheet, Form Number CSP-366L.

C.P. RANGE	1M/2MP	2M/3MP	C.P. RANGE	3M/4MP	4M/6MP	6M/8MP	8M/10MP
0.2-0.9	22335-0.5	22336-0.5	.5-2.4	10362-1	10462-1	10662-1	10845-1
1.0-2.3	22335-1	22336-1	2.5-5.9	10362-4	10462-4	10662-4	10845-4
2.4-5.5	22335-4	22336-4	6.0-13.9	10362-10	10462-10	10662-10	10845-10
5.6-13.9	22335-10	22336-10	14.0-31.0	10362-20	10462-20	10662-20	10845-20
14.0-27.9	22335-20	22336-20	31.1-72.9	10362-50	10462-50	10662-50	10845-50
28.0-33.9	22335-30	22336-30	73.0-150.0	10362-100PH	10462-100PH	10662-100PH	10845-100PH
34.0-74.9	22335-55	22336-55					
75.0-104.9	22335-90PH	22336-90PH					
105.0-147.9	22335-125PH	22336-125PH					

**Springs for each valve size are interchangeable. The Cracking Pressure range can be changed by replacing the spring with one covering the desired range.

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2301 WARDLOW CIRCLE
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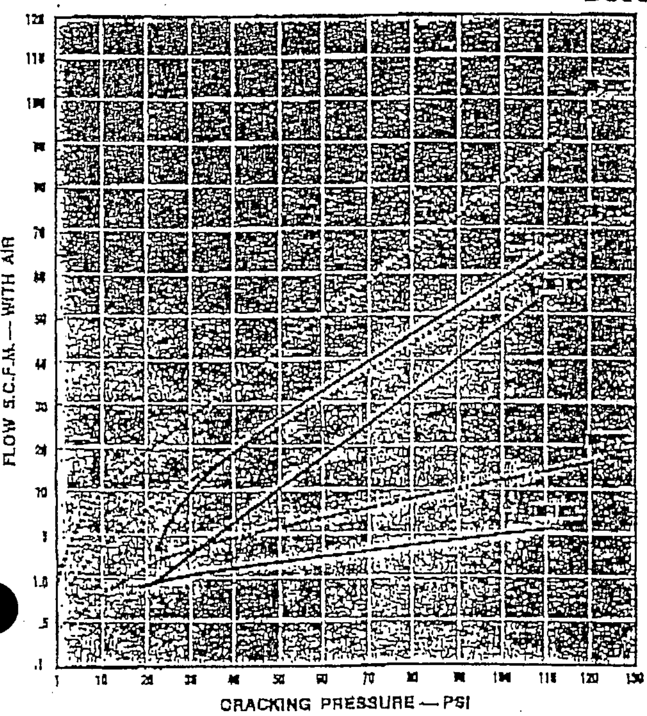
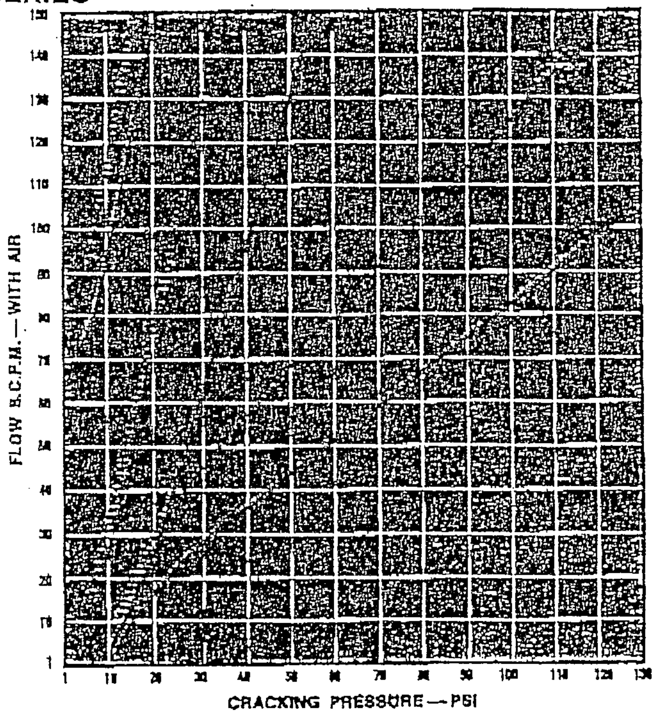
RELIEF VALVES
0 Series
5-150 PSI

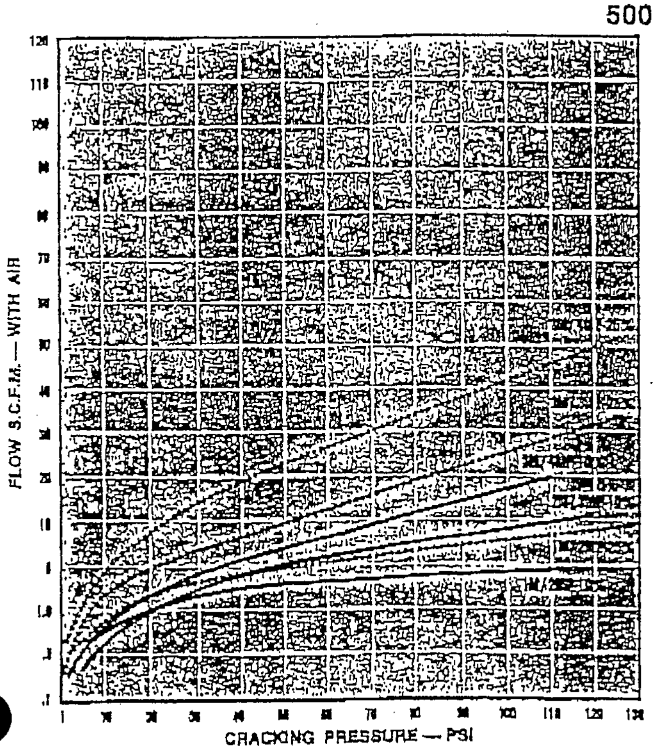
Use the curves on this side to determine the maximum allowable flow rate where the maximum over-pressure is known. Curves presented show 10% and 25% pressure buildup over cracking pressure for each valve size.
(Solid Line indicates 10% Pressure Buildup; Dash Line indicates 25% Pressure Buildup.)

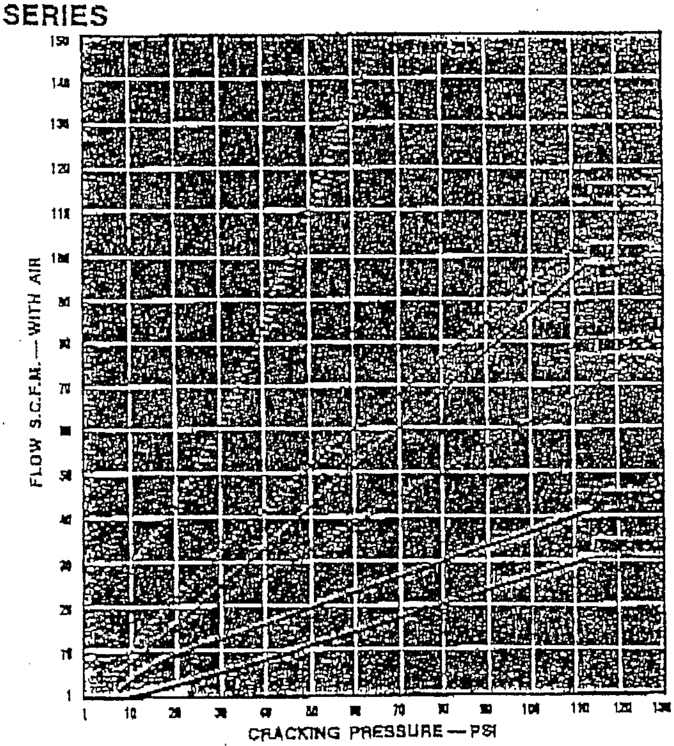
D500 SERIES





500 SERIES





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301 WARDLOW CIRCLE
P.O. BOX 3300
CORONA, CALIFORNIA 91718

Date: Sat, 10 May 2003 09:33:58 -0400
From: Munir Jirmanus <mjirmanus@janis.com>
To: 'Jeremy Dodd' <dodd@nevis.columbia.edu>
Subject: RE: Columbia/BNL 16CNDT cryostat

Dear Jeremy,

I will attempt to answer all your questions in the same order they appeared.

1. What venting scenarios were considered in determining the size (1/2") of the pressure relief valves on the cryostat?

The pressure relief valves are selected based on our practical knowledge developed over the years since our company was established (1961).

2. The LN2 reservoir has three open holes at the top, for filling and venting - is there a risk of back-flow of water vapor into the holes with associated ice build-up, and if so, what modifications can be made to prevent this?

The risk is minimal. You can prevent it by adding either "Bunsen" type valves (rubber tubes with a slit for venting and sealed with a stopper), simple rubber tubes long enough to make a U turn and end up pointing downwards, or more costly pressure relief valves (or one valve with the three exits joined together) added to the entrances. Typically this can be done using an O-ring compression seal against the outgoing tubes, soldered to a cap with the pressure relief valves threaded in position.

3. The vacuum vessel is designed to ASME code (though not stamped) - are the reservoirs also to code?

The reservoirs are not designed to ASME code because this would contradict the cryogenic requirements of this unit (thin-wall tubes to reduce the heat load into the two reservoirs). These reservoirs are not vacuum vessels, and they operate at atmospheric pressure or slightly (~2 psi) over. The innermost tube (0.75" OD x 0.0625" wall) is designed to operate at high pressure and is thus designed to code.

Best regards,

Munir

****
PS. Please acknowledge receipt of this email message to ensure the continuity of communications.
****

Munir N. Jirmanus, Ph.D.
Vice President - Technical Sales & Development
Janis Research Company, Inc.
2 Jewel Drive - P.O. Box 696
Wilmington, MA 01887 USA

Telephone : (978) 657-8750, X-110
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E-mail : janis@janis.com or mjirmanus@janis.com
http://www.janis com

-----Original Message-----

Date: Thu, 16 Oct 2003 08:11:59 -0400
From: Munir Jirmanus <mjirmanus@janis.com>
To: Jeremy Dodd <dodd@nevis.columbia.edu>
Subject: RE:

Dear Jeremy,

We also get pressure relief valves from Generant Co. of Butler, NJ [www.generant.com Tel. 973-838-6500]. The ones used from Generant are model VRV-250BB-4.

regards,

Munir

-----Original Message-----
From: Jeremy Dodd [mailto:dodd@nevis.columbia.edu]
Sent: Friday, October 10, 2003 12:29 PM
To: Munir Jirmanus
Cc: Tom Pasakarnis
Subject: RE:

Dear Munir,

In checking the relief valves on the cryostat yesterday, I noted that the two relief valves on the LHe reservoir are not from CircleSeal (as are the others). One appears to be from Goddard Valve Corp, although there is no part number; the other looks somewhat similar, but does not have a name or part number on it.

It will be very helpful to us if you could provide some details on these two relief valves.

Many thanks,
Jeremy

Jeremy Dodd	Nevis Laboratories
Tel: (914) 591 2821	Columbia University
Fax: (914) 591 8120	P.O. Box 137
e-mail: dodd@nevis.columbia.edu	Irvington
WWW: www.nevis.columbia.edu/~dodd	NY 10533

GENERANT

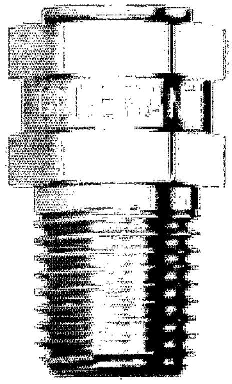
VENT RELIEF VALVE

1/8" - 1" NPT
.5 - 150 Psig

SERIES VRV

Description

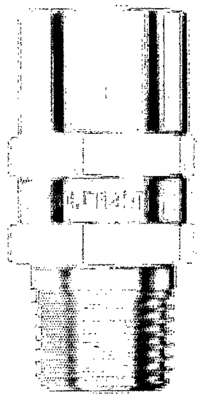
A compact, highly accurate, direct acting pressure relief valve. Factory preset to desired crack pressure and/or flow specifications. Internal adjustment provides tamper proof safety against inadvertent pressure changes. Available vent to atmosphere or inline configurations in brass, aluminum and 316 stainless steel. Valves feature a Quad ring seal which provides for extreme accuracy and repeatability with a narrow reseal band. Optional deflector cap increases flow capacity and provides for deflection of discharge.



VRV
Vent to Atmosphere

Features and Benefits

- Accurate and Repeatable Cracking Pressure
- 100% Factory Preset and Tested
- Zero Leakage to 95 - 98% of Set Pressure
- Tamper Proof Adjustment
- Excellent Reseal Performance
- Compact Size

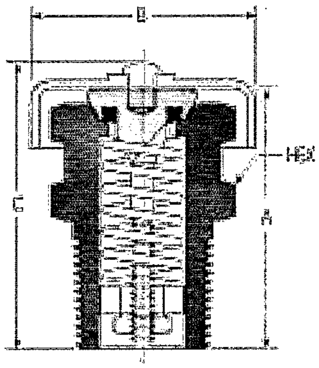


VRVI
Inline

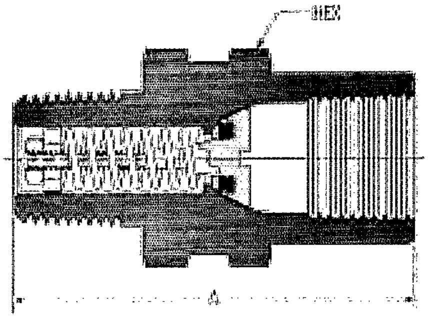
Technical Data

- Set Pressure Range: 0.5 to 150 Psig (0.3 to 10.3 bar)
- Inline Valves *(Series VRVI)*:
  Proof Pressure: 400 Psig (28 bar)
  Burst Pressure: >500 Psig (34 bar)
- Set Pressure Tolerance: Factory preset +/- 5% on increasing pressure
- Reseal:
  80% of Set Pressure for valves specified 1 - 10 Psig (0.07 to 0.7 bar)
  92% of Set Pressure for valves specified 10 - 150 Psig (0.7 to 10.3 bar)
- Temperature Range: -320˚F to 400˚F (-195˚C to 205˚C)
  (based on seal selection, see ordering information)

SERIES VRV
VENT RELIEF VALVE



VRV & VRVD
Vent to Atmosphere



VRVI
Inline

Dimensional Data

Pipe Size NPT[1]	VRV & VRVD				VRVI	
	A	B	C	Hex	A	Hex
1/8"	.97	.69	1.10	1/2"	N/A	
1/4"	1.20	.92	1.32	5/8"	1.62	3/4"
3/8"	1.24	1.17	1.38	3/4"	2.12	7/8"
1/2"	1.75	1.40	1.92	1"	2.20	1"
3/4"	2.25	1.73	2.44	1-1/8"	2.72	1-1/4"
1"	3.12	1.94	3.29	1-1/2"	3.62	1-1/2"[2]

1 *Available with male straight thread connections. (SAE J1926, MS33656 with cone point removed)consult factory*
2 *Machined from 1-3/4" Round with 1-1/2" wrench flats*
Dimensional data is stated in inches

Materials of Construction

Component	Valve Body Material		
	Brass	Aluminum[1]	Stainless Steel
Valve Body	Brass, ASTM B16 *(Nickel Plated, ASTM B689)*	2024 Aluminum ASTM B211 *(Clear Anodized, ASTM B580)*	316 SS, ASTM A479
Stem	Brass, ASTM B16		
Spring Retainer[2]			
Seal[3]	As specified, see ordering information		
Spring	302 SS/17-7 PH, ASTM A313		
Locknut	18-8 SS		
Deflector Cap and Rivet	2024 Aluminum ASTM B211 *(Clear Anodized, ASTM B580)*		

1 *Available in 1/8" and 1/4" valves only*
2 *All 1/8" and 1/4" valves have 316 stainless steel (ASTM A479) retainers*
3 *Lubricated with Krytox™ GPL 202*

SERIES VRV
VENT RELIEF VALVE

Flow Data, Series VRV (Vent to Atmosphere)

Nominal Spring		1		5		10		20		50		100		150	
Set Pressure Range		0.5 - 2.5		2.6 - 7.5		7.6 - 15		16 - 35		36 - 75		76 - 125		126 - 150	
Valve Size	Orifice	Flow (SCFH)	Kd	Flow (SCFH)	Kd	Flow (SCFH)	Kd	Flow (SCFH)	Kd	Flow (SCFH)	Kd	Flow (SCFH)	Kd	Flow (SCFH)	Kd
1/8" NPT (VRV - 125)	0.187	7.7	0.03	34	0.06	55	0.07	90	0.08	260	0.12	500	0.13	610	0.11
1/4" NPT (VRV - 250)	0.275	8	0.01	37	0.03	69	0.04	123	0.05	515	0.11	2011	0.24	2290	0.19
3/8" NPT (VRV - 375)	0.345	12	0.01	58	0.03	108	0.04	150	0.04	550	0.07	1300	0.1	1140	0.06
1/2" NPT (VRV - 500)	0.410	50	0.04	110	0.04	150	0.04	220	0.04	1458	0.14	3725	0.2	4000	0.15
3/4" NPT (VRV - 750)	0.570	Consult Factory		Consult Factory		Consult Factory		Consult Factory		Consult Factory		Consult Factory		Consult Factory	
1" NPT (VRV - 1000)	0.785	Consult Factory		Consult Factory		Consult Factory		Consult Factory		Consult Factory		Consult Factory		Consult Factory	

Flow Data, Series VRVD (Vent to Atmosphere, with Deflector Cap)

Nominal Spring		1		5		10		20		50		100		150	
Set Pressure Range		0.5 - 2.5		2.6 - 7.5		7.6 - 15		16 - 35		36 - 75		76 - 125		126 - 150	
Valve Size	Orifice	Flow (SCFH)	Kd	Flow (SCFH)	Kd	Flow (SCFH)	Kd	Flow (SCFH)	Kd	Flow (SCFH)	Kd	Flow (SCFH)	Kd	Flow (SCFH)	Kd
1/8" NPT (VRVD - 125)	0.187	10.3	0.04	39	0.07	95	0.12	100	0.09	280	0.13	580	0.15	780	0.14
1/4" NPT (VRVD - 250)	0.275	11	0.02	40	0.03	100	0.05	172	0.07	2340	0.5	4272	0.5	6650	0.55
3/8" NPT (VRVD - 375)	0.345	13	0.01	77	0.04	130	0.05	195	0.05	738	0.1	4353	0.33	6275	0.33
1/2" NPT (VRVD - 500)	0.410	60	0.05	246	0.09	420	0.11	658	0.12	2605	0.25	Consult Factory		Consult Factory	
3/4" NPT (VRVD - 750)	0.570	Consult Factory		Consult Factory		Consult Factory		Consult Factory		Consult Factory		Consult Factory		Consult Factory	
1" NPT (VRVD - 1000)	0.785	Consult Factory		Consult Factory		Consult Factory		Consult Factory		Consult Factory		Consult Factory		Consult Factory	

Flow Data, Series VRVI (Inline)

Nominal Spring		1		5		10		20		50		100		150	
Set Pressure Range		0.5 - 2.5		2.6 - 7.5		7.6 - 15		16 - 35		36 - 75		76 - 125		126 - 150	
Valve Size	Orifice	Flow (SCFH)	Kd	Flow (SCFH)	Kd	Flow (SCFH)	Kd	Flow (SCFH)	Kd	Flow (SCFH)	Kd	Flow (SCFH)	Kd	Flow (SCFH)	Kd
1/4" NPT (VRVI - 250)	0.187	7.7	0.03	34	0.06	55	0.07	90	0.08	260	0.12	500	0.13	610	0.11
3/8" NPT (VRVI - 375)	0.275	8	0.01	37	0.03	69	0.04	123	0.05	515	0.11	2011	0.24	2290	0.19
1/2" NPT (VRVI - 500)	0.345	12	0.01	58	0.03	108	0.04	150	0.04	550	0.07	1300	0.1	1140	0.06
3/4" NPT (VRVI - 750)	0.410	50	0.04	110	0.04	150	0.04	220	0.04	1458	0.14	3725	0.2	4000	0.15
1" NPT (VRVI - 1000)	0.570	Consult Factory		Consult Factory		Consult Factory		Consult Factory		Consult Factory		Consult Factory		Consult Factory	

Notes to Flow Data

- Flow and Kd (discharge coefficient) are stated at 110% accumulation above set point with Nitrogen and Zero Downstream Pressure
- Interpolate charts for set pressures between points given
- Restrictions in the inlet or outlet piping may reduce flow
- Exceeding 115% accumulation may result in valve failure
- Generant offers complete design assistance. Consult factory for correct relief valve sizing
- Individual flow curves available on request
- Orifice sizes are stated in inches

GENERANT
www.generant.com
1865 Route 23 South PO Box 768 Butler, New Jersey 07405 973.838.6500 Fax 973.838.4888

SERIES VRV
VENT RELIEF VALVE

Ordering Information

VRV - 125B - V - 15

SERIES

VRV - Vent to Atmosphere
VRVD - Vent to Atmosphere with Deflector Cap
VRVI - Inline Relief (Male x Female)

PIPE SIZE

125 - 1/8"
250 - 1/4"
375 - 3/8"
500 - 1/2"
750 - 3/4"
1000 - 1"
NPT threads per ANSI/ASME B1.20.1.

MATERIAL CODE

B - Brass
A - Aluminum
SS - 316 SS
For other materials, consult factory

NOMINAL SET PRESSURE

Specify .5 - 150 Psig
(Teflon™ Seals not available below 20 Psig)
Valves that are not actuated for a period of time may exhibit higher initial crack pressure (first bubble) than subsequent cycles

SEAL MATERIAL

V - Viton™, -20°F to 400°F (-29°C to 205°C)
B - Buna-N, -40°F to 250°F (-40°C to 121°C)
N - Neoprene, -40°F to 250°F (-40°C to 121°C)
EP - Ethylene Propylene, -65°F to 300°F (-54°C to 148°C)
FS - Fluorosilicone, -20°F to 350°F (-62°C to 176°C)
S - Silicone, -65°F to 400°F (-54° C to 205°C)
T - Teflon™, -320°F to 400°F (-220°C to 205°C)
Teflon™ seals may not reseal bubble tite

OPTIONS

Oxygen cleaning, alternative seals and other thread configurations, consult the factory

Viton, Krytox & Teflon - ™DuPont

PROPER COMPONENT SELECTION - When specifying a component, the total system design must be considered to ensure safe and trouble-free performance. Intended component function, materials compatibility, pressure ratings, installation, environment and maintenance are the responsibility of the system designer.

GENERANT

version 02.25.03

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Instructions

Fill in Orifice Size. (List of Generant Orifices on sheet 2)
Fill in Discharge Coeficient. (List of Generant Kd on sheet 2)
Fill in Upstream Pressure, Downstream Pressure and Temperature.
Fill in "Yes" for CO2 Applications, or N/A.
Select Gas Density, Gas Constant and Gas Ratio

Read

Calculated Flow in blue boxes

Orifice Flow Calculator GAS

Rev D, 03/18/02

GENERANT

Part no:
Remarks: **Calculations@110% of set pressure**

INPUT		CALCULATED	
Orifice Diameter (in)	0.275	Orifice Area (in2)	0.06
Orifice Discharge Coefficient	0.110	Inlet Pressure (psia)	59.70
Upstream Pressure (psig)	45.0	Outlet Pressure (psia)	14.70
Downstream Pressure (psig)	0.0	Temperature (R)	18.00
Upstream Temperature (F)	70	Critical Pressure Ratio	0.49
If Calculating Co2 Flow, type "Yes" an	N/A	Upstream Density (lbm/ft3)	0.04
use Air values from below		Gc (ft lbm /lb /s2)	32.17
Gas Density, Standard (lbm/ft3)	0.0103		
= 0.0749 (Air)		**Gas Flow Rate (lbm/s)**	**0.02**
= 0.1034 (Argon)		**Gas Flow Rate (lbm/min)**	**1.16**
= 0.0103 (Helium)		**Gas Flow Rate (lbm/hr)**	**69.44**
= 0.00521 (Hydrogen)		**Gas Flow Rate (SCFM)**	**112.35**
= 0.0724 (Nitrogen)		**Gas Flow Rate (SCFH)**	**6,741.28**
= 0.0828 (Oxygen)			
Gas Constant (ft lb /lbm /R)	386.00	**Carbon Dioxide Flow (SCFM)**	**N/A**
= 53.34 (Air)			
= 38.65 (Argon)			
= 386.0 (Helium)			
= 766.4 (Hydrogen)			
= 55.15 (Nitrogen)			
= 48.28 (Oxygen)			
Upstream Gas Ratio of specific heats	1.670		
= 1.40 for diatomic gasses (ex: air, nitrogen, oxygen, hydrogen)			
= 1.67 for monatomic gasses (ex: helium, argon)			

Assumptions: Fluid behaves as an ideal gas.

Date: Thu, 16 Oct 2003 11:11:39 -0400
From: Jeremy Dodd <dodd@nevis.columbia.edu>
To: kcwu@bnl.gov
Subject: Nevis/BNL LHe cryostat

Dear K.C.

Janis states that the LHe reservoir should hold 4 atm. (see below).

Cheers,
Jeremy

---------- Forwarded message ----------
Date: Thu, 9 Oct 2003 09:42:42 -0400
From: Munir Jirmanus <mjirmanus@janis.com>
To: Jeremy Dodd <dodd@nevis.columbia.edu>
Cc: Tom Pasakarnis <tpasakarnis@janis.com>
Subject: RE:

Dear Jeremy,

The helium reservoir should be able to withstand a pressure of 4 atmospheres.

Regards,

Munir

Date: Thu, 30 Oct 2003 16:14:28 -0500
From: "Wu, Kuo-Chen" <kcwu@bnl.gov>
To: Jeremy Dodd <dodd@nevis.columbia.edu>
Cc: "Sondericker, John" <jsonder@bnl.gov>
Subject: RE: Generant Series VRV / Industrial Flow Calc. (fwd)

Dear Jeremy,

I am kind of busy these days and I am taking tomorrow off.

>From what you told me:

1). Vendor's information on pressure rating.

2). Relief valve sizing according to the capacity given by the vendor.

The relief system for the e-bubble experiement is acceptable to me.
Actually, the inlet temperature can be substantially lower than 70 F.

I do not know if other member like Steve Kane will insist on ASME pressure vessel code which apparently can't be done.

Have a nice weekend.

K. C.

-----Original Message-----
From: Jeremy Dodd [mailto:dodd@nevis.columbia.edu]
Sent: Tuesday, October 28, 2003 11:09 AM
To: Wu, Kuo-Chen
Subject: Generant Series VRV / Industrial Flow Calc. (fwd)

Dear K.C.

Here are the specs. on our relief valve provided by Generant.

Best wishes,
Jeremy

---------- Forwarded message ----------
Date: Fri, 24 Oct 2003 15:56:49 -0400
From: Kazimierz A. Lesiczka <Kaz@generant.com>
To: dodd@nevis.columbia.edu
Subject: Generant Series VRV / Industrial Flow Calc.

Thank you for your request.
If you require anything else please contact me.

Thank you

Kaz Lesiczka
Technical Sales
Generant Company inc
Butler, NJ 07405
PH:973-838-6500
FX:973-838-4888
kaz@generant.com

3. Prepare test plan (and witnessing) for eBubble chamber 200 psi pressure test and test of relief valves

Our June response to Richard Thomas is included below:

We are coordinating with Mike Gaffney and Steve Kane of the CSC to perform the pressure test. Steve is helping us prepare for the test, and Mike will oversee and witness it.

For our measurements of interest, we would like to be able to operate the chamber at up to 10 bar (approx. 145 psia) internal pressure. For certification for this pressure, we therefore plan on testing to 125% of 145 psia, or 181 psia. Under normal operating conditions, the chamber will sit inside a vacuum vessel, and so will 'see' the full 145 psia differential pressure.

For the pressure test, following discussions with Mike Gaffney and Steve Kane, we propose a two-stage test procedure, with both stages being pneumatic tests with helium gas:

<u>Stage 1:</u>
A standalone bench test of the chamber, in Building 832. Since we wish to test the chamber to 181 psi differential pressure, and we plan on performing this test at external atmospheric pressure, the internal pressure for this test will be (181+14.5), or 195 psia. Mike Gaffney has recommended that we pressurize to 195 psia, and observe the chamber for approx. ten minutes. Tom Muller has agreed that this test can be performed in Building 832, and we will work with Steve, Mike and Tom, to ensure adequate protective shielding for the test.

<u>Stage 2:</u>
Assuming that the Stage 1 test is successful, we propose to then test the chamber in situ in the cryostat, at maximum internal pressure (145 psia) under normal operating conditions, i.e. with external vacuum. This will test the full system. We intend to attach a leak-tester to the vacuum vessel also during this test, to allow tests for leaks in the final system.

<u>Current status:</u> (June)
We have been able to borrow equipment for the pressure tests from CAD, and are currently discussing detailed procedures with Steven Kane. Steve has asked for some

P.T.O.

further information concerning the welds on the chambers, stresses, flange thicknesses, and stresses on the central support tube, which we are currently working on.

Since June, we have continued to work with Steve Kane of the Cryogenic Safety Committee. Steve requested further studies on the strength of the flanges, on which we were helped by R. Alforque (see report, Attachment 1) and by C. Pai (see report, Attachment 2). With these studies in hand, we were able to perform a successful pressure test of the chamber on 27 October, 2003. The test was performed by Steve, and witnessed by T. Monahan (see Attachment 3).

Attachments:
1. Report by R. Alforque.
2. Report, and figures, of C. Pai.
3. T. Monahan notice of successful pressure test.

Nevis Labs e-Chamber
by Rudy Alforque

Basic Parameters:

$d1 := 4.25 \cdot in$; O-ring Groove, $ds := 4.94 \cdot in$

$d2 := 5.5 \cdot in$; Joint Eff., $E := 1$ (Assume, seamless)

$P := 150 \cdot psi$; $pi := 3.1416$

$r := \frac{d1}{2}$; Allowable Stress(SS304), $Sa := 18800 \cdot psi$

$r = 2.125\,in$

I. Cylinders

Required thickness of the inner shell under 10 bar of pressure
per ASME B&PV Code, UG-27:

$$t := \frac{P \cdot r}{Sa \cdot E - 0.6P}$$

$$t = 0.017\,in$$

**The inner tube has 0.12 wall, so it's adequate for an internal pressure of 10 bar.
The outer shell has 0.25 wall and it is more than adequate
for a 1 bar load, external pressure.**

II. Welds (End Flanges to Cylinders)

$h := 0.1 \cdot in$, fillet weld size

Since the vacuum space between the cylinders is small, the dominant weld load would be shear. The outer cylinder is quite stiff to prevent any significant edge rotation.

For conservatism, let the full force due to the 10 bar internal pressure be carried by the inner weld in tension. The shear on the weld is:

$A := pi \cdot \left(\frac{ds}{2}\right)^2$ --> Area under pressure (ds = seal dia)

$C := pi \cdot d1$ --> Weld length

$Aw := 0.707 \cdot h \cdot C$ $F := P \cdot A$

$Sw := \frac{F}{Aw}$ --> shear on the weld

$Sw = 3.046 \times 10^3\,psi$

Note: This is much less than 18,800 psi! And of course the outer weld also shares the load, thus the weld stress is even lower.

III. Cover Flange Penetrations:

(Refer to UG-34, and Fig. UG-34j, ASME Code; Assume a self-energizing gasket such as an O-ring):

$$hg := 0.594 \cdot in$$

$$c := 0.3$$

$$W := F$$

$$W = 2.875 \times 10^{3}\, lbf$$

Required thickness:

$$tf := ds \cdot \sqrt{\left(\frac{c \cdot P}{Sa \cdot E}\right) + \left[\frac{1.9 \cdot W \cdot (hg)}{\left[Sa \cdot (E) \cdot ds^{3}\right]}\right]}$$

$$tf = 0.306\, in$$

The cover flange is 0.5 in thick, so its ok. There are several penetrations but the removed material is replaced by a stiff feedthru, etc. and thus, the flange strength is not adversely affected. Assumption: Welds(no dimension shown) are as strong as the parent metal.

IV. O-ring Seals

As the flange thickness is more than the required thickness, the thru-thickness deformation should be insignificant and the O-ring, which is generally considered as a self-energizing and self-sealing gasket, should be ok.

Dr. Yonglin Ju

Mechanical design for EBC

1. Stainless steel material properties (T=300K)

Density ρ :	$\rho\_s := 7800$	[kg/m^3]
Thermal conductivity λ :	$\lambda\_s := 15.2$	[W/m-K]
Thermal expansion ε :	$\varepsilon\_s := 6.6 \cdot 10^{-4}$	[K^-1]
Specific heat Cp :	$Cp\_s := 500$	[J-kg/m-K]
Youngs modulus E :	$E\_s := 158 \cdot 10^{9}$	[Pa]
Apparent elastic limit σ :	$\sigma\_s := 129 \cdot 10^{6}$	[Pa]

2. Dimension of LHe e-Bubble Chamber

Inner di ameter	$Di1 := 4.252$	[in]	$Di := Di1 \cdot \left(25.4 \cdot 10^{-3}\right)$	$Di = 0.108$	[m]
Inner length	$Hi1 := 6.7$	[in]	$Hi := Hi1 \cdot \left(25.4 \cdot 10^{-3}\right)$	$Hi = 0.17$	[m]
Wall thickness δ :	$\delta 0 := 0.120$	[in]	$\delta := \delta 0 \cdot 25.4$	$\delta = 3.048$	[mm]
Top flange :	$\delta t0 := 0.375$	[in]	$\delta t := \delta t0 \cdot 25.4$	$\delta t = 9.525$	[mm]
Bottom flange :	$\delta b0 := 0.445$	[in]	$\delta b := \delta b0 \cdot 25.4$	$\delta b = 11.303$	[mm]

3. Chamber working condition

Internal working pressure P : $P := 10 \cdot 10^{5}$ [Pa]

Weld factor e_w : $e\_w := 0.8$

4.Wall thickness calculation

$$\delta\_min := \frac{P \cdot Di}{2 \cdot \sigma\_s \cdot e\_w - 1.2\,P}$$

$\delta\_min = 5.263 \cdot 10^{-4}$ [m] $\quad$ $\delta 1 := \delta\_min \cdot 1000$ $\quad$ $\delta 1 = 0.526$ [mm]

5.Wall thickness design (safety factor =3)

$\delta\_design := 3 \cdot \delta 1$ $\quad$ $\delta\_design = 1.579$ [mm] $<$ $\delta = 3.048$ [mm]

Dr. Yonglin Ju

Sapphire window design for EBC

1. Sapphire material properties (t=300K)

Density ρ **:** $\rho := 3.97\cdot 10^3$ [kg/m^3]

Thermal conductivity λ **:** $\lambda\_s := 27.21$ [W/m-K]

Thermal expansion ε **:** $\varepsilon\_s := 5.0\cdot 10^{-6}$ [K^-1]

Specific heat Cp : $Cp\_s := 419$ [J-kg/m-K]

Youngs modulus E : $E\_s := 335\cdot 10^9$ [Pa]

Apparent elastic limit σ **:** $\sigma\_s := 275\cdot 10^6$ [Pa]

2. Window dimension

Full diameter Do : $Do := 1.96\cdot\left(25.4\cdot 10^{-3}\right)$ $Do = 0.05$ [m]

Free diameter Di : $Di := 0.99\cdot\left(25.4\cdot 10^{-3}\right)$ $Di = 0.025$ [m]

Thickness δ **:** $\delta 0 := 0.25\cdot\left(25.4\cdot 10^{-3}\right)$ $\delta 0 = 6.35\cdot 10^{-3}$ [m]

3. Window working condition

Internal working pressure P : $P := 10\cdot 10^5$ [Pa]

For a clamped window K : $K := 0.866$

4. Window thickness calculation

$$\delta\_min := \left[\frac{\left(K\cdot P\cdot Di^2\right)}{\sigma\_s}\right]^{0.5} \qquad \delta\_min = 1.411\cdot 10^{-3} \qquad \delta := \delta\_min\cdot 1000 \qquad \delta = 1.411$$ [mm]

5. Window thickness design (safety factor=3)

$$\delta\_design := 3\cdot\delta \qquad \delta\_design = 4.233$$ [mm] < $\delta 0\cdot 1000 = 6.35$ [mm]

Structural Analysis: **C. Pai 9-18-2003**

Subject: E-Chamber Top Plate and Flange Strength Analysis.

1. Summaries:
   a. The tightening torque (from MDC) for the 5/16-18 bolt is about 12 to 15 ft-lb. In this calculation 12 ft-lb (144 in-lb) was used in the model. This torque will induce 2304 lb tension in each bolt. The total clamping force for the whole flange is 27648 lb. In the model this force is simulated by thermal shrink in the bolt element. The contact surface between top plate and flange is modeled by contact element to simulate a compression only condition. The E-chamber assembly is shown in Fig. 1. The finite element model is shown in Fig. 2 and 3.

   b. The O-ring repelling force from the .01 inches compression is about 320 lb. In the model this force is simulated as pressure applied in the O-ring groove . The clamping force to resist 10 bar (150 psi) internal pressure is about 2385 lb.

   c. The ratio of total bolt tension to needed clamping force is about 10.

   d. The initial bolt tensional stress without internal pressure is $\sigma = 45{,}283$ psi (Fig. 4, 6). When internal pressure applied the tensional stress increased to 46,191 psi (Fig. 5,7). The change in the bolt load is about 2%.

   e. The maximum contact pressure by the bolt tension is 7600 psi (Fig. 8). When the 10 bar internal pressure applied this pressure will be redistributed and the maximum pressure is 11000 psi (Fig. 9). The gap between the contact surfaces will be opened up about .00043 inches (Fig. 10, 11) in the inner edge of the contact surface. This is a small change compare to the .01 inches compression of the O-ring seal.

   f. When bolted without internal pressure , the maximum stress in the top plate is around the bolted area, $\sigma = 26{,}536$ psi (Fig. 12,13). When pressure applied this stress reduced to 25,764 psi (Fig.14,15). This stress is a localized stress due to high local bolting force and the nature of finite element modeling. In the real world this stress will be reduced by washers and rounded corners. The stress in the center and edge of the feedthrough holes is about 13,206 psi (Fig.14,15).

2. Model:
   A three dimensional, quarter size, ANSYS model (Fig. 1, 2, 3) was built to simulate this structure. The flange contact interface was modeled by contact element to check if gap opening occurred when internal pressure applied. The bolt tension is simulated by thermal shrinkage applied in the bolt. The compression of O-ring was simulated by pressure in the O-ring groove.

3. Materials:

a. Top plate :

Size: 7.0" O.D, .375" thick.

Material: 304 SST

$E = 30e6$ psi

$\upsilon = .3$

b. Chamber flange:

Size: 4.5"ID, 7.0" OD, .5" thick,

Material: 304L SST

$E = 30e6$ psi

$\upsilon = .3$

c. O-ring : No. 2-048

Size: 4-7/8"(OD) x 4-1/4" (ID) x .07" (W)

Material: Viton

$E = 2000$ psi

$\upsilon = .499$

d. 5/16-18 Bolt:

Size: Nominal dia. 5/16"

Cross section area: .0524 in^2.

Strength of Bolt:

Grade 5: 85,000 psi (min).

3. Strength of SST 304:

ASME Allowable stress : 15,700 psi

Yield stress: 25,000 psi

Ultimate stress: 70,000

4. Loading condition:

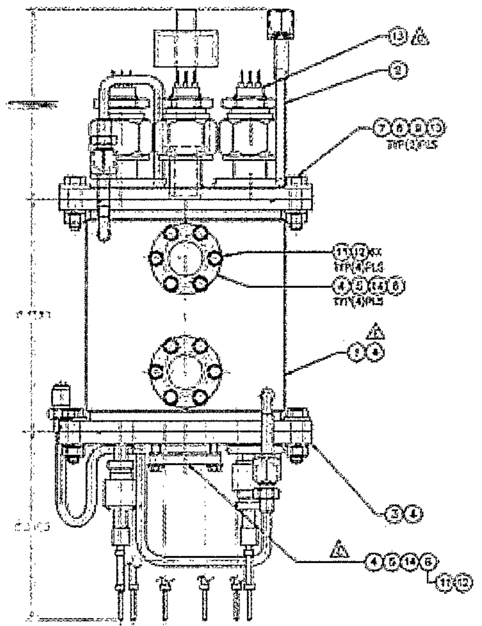
a. Initial condition: Bolted without internal pressure

Bolt tension: 27648 lb total from 12 bolts.

O-ring compression load: 320 lb.

b. Operation condition: Bolted with 10 bar (150 psi) internal pressure.

Fig. 1 E-Chamer Assembly



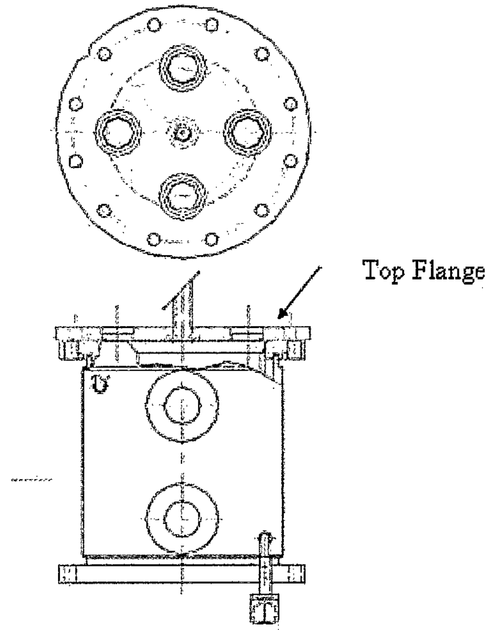


Fig. 2 Top Plate and Flange Model

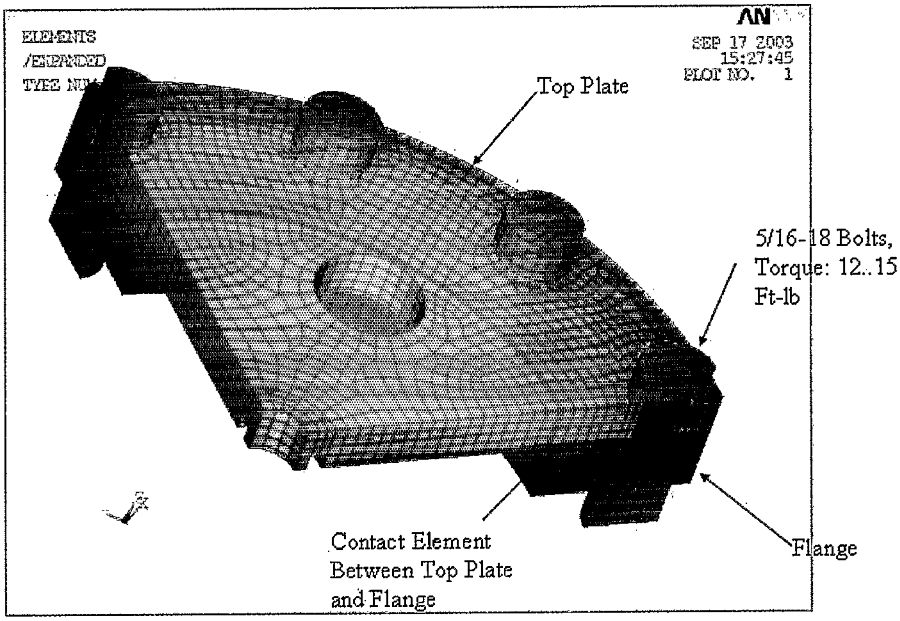


Fig. 3 Top Plate and Flange Model

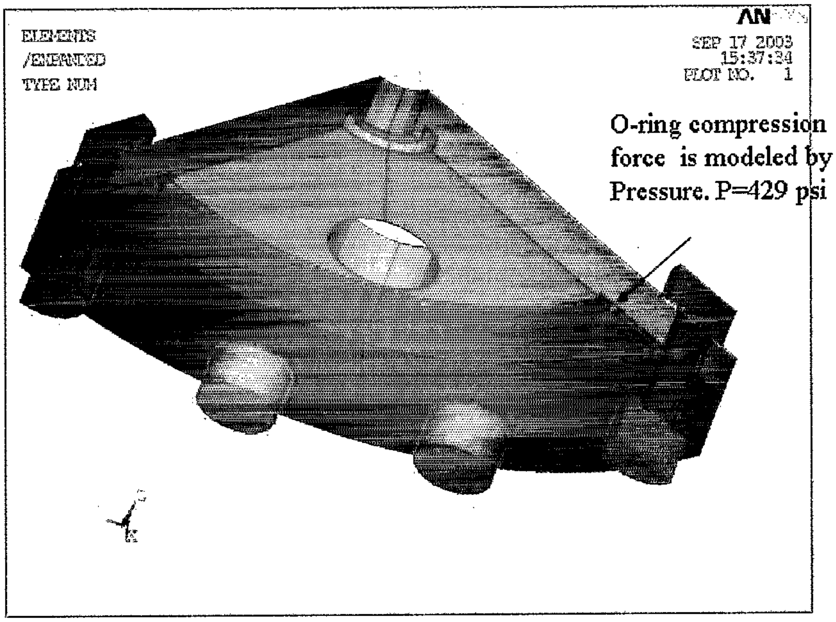


Fig. 4 Von Mises Stresses in the Assembly, Bolt Preload only

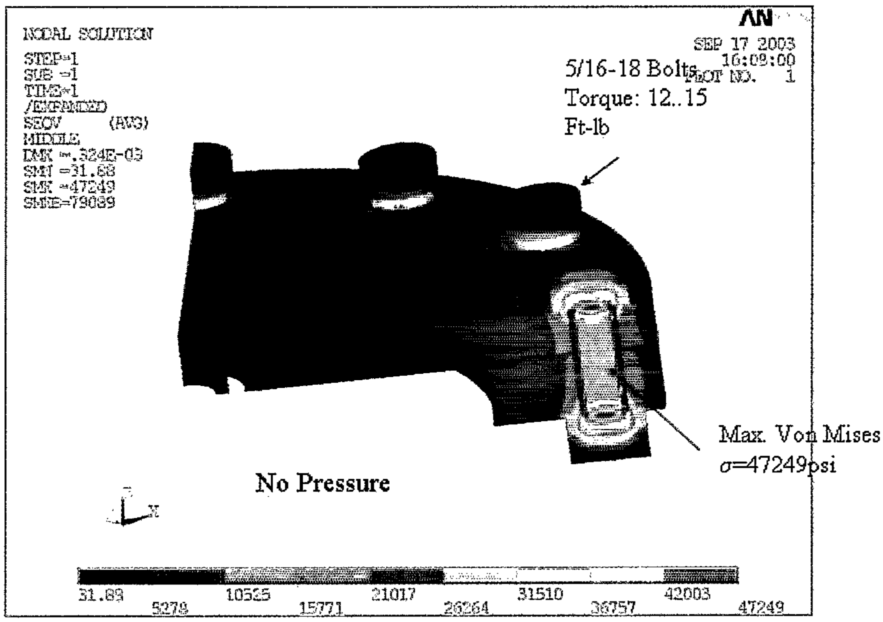


Fig. 5 Von Mises Stresses in the Assembly, with 150 psi Pressure

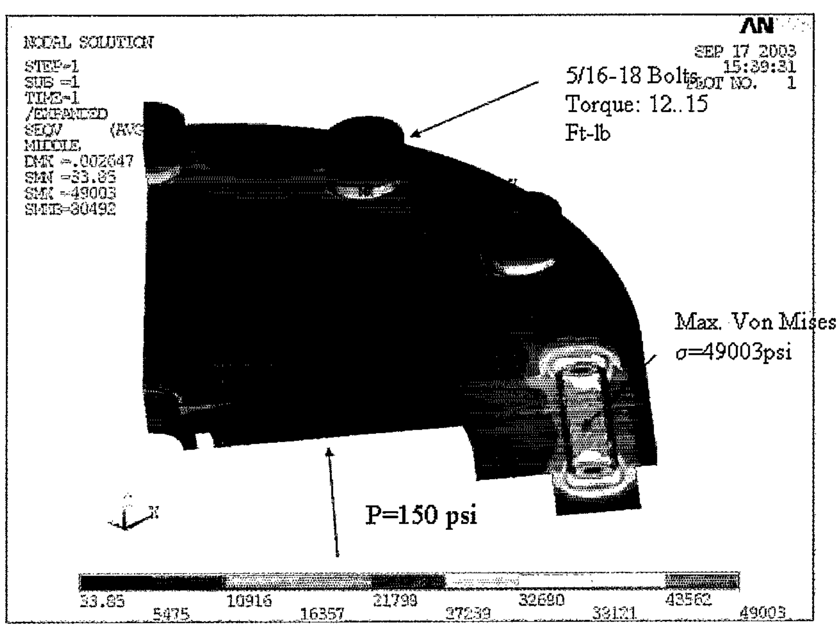


Fig. 6 Vertical Stresses in the Assembly, Bolt Preload only

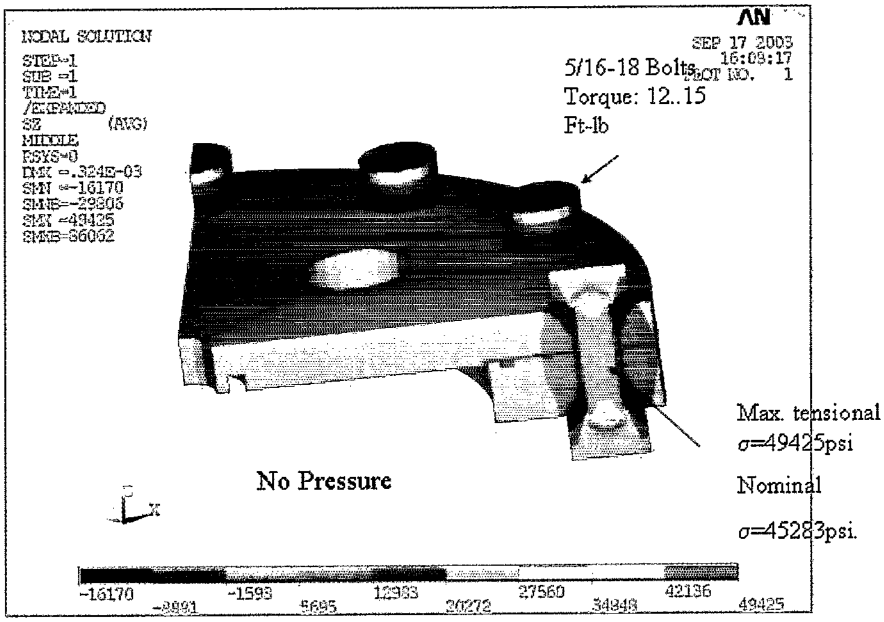


Fig. 7 Vertical Stresses in the Assembly, with 150 psi Pressure

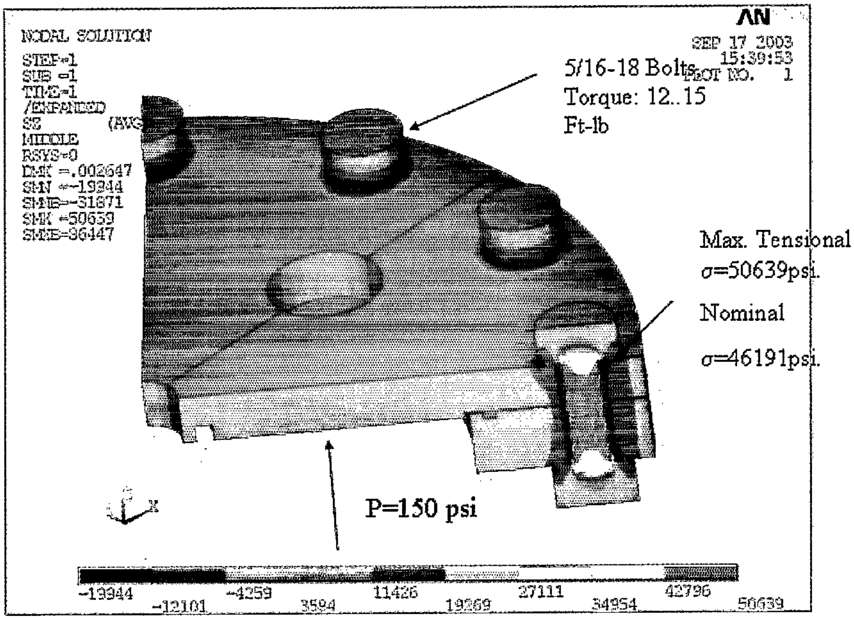


Fig. 8 Contact surface pressure, without Pressure

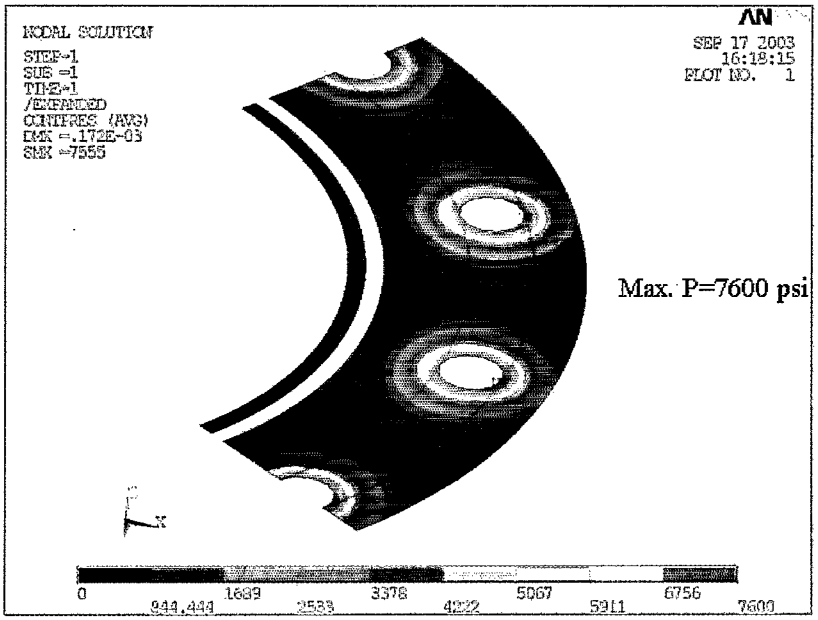


Fig. 9 Contact surface pressure, with 150 psi Pressure

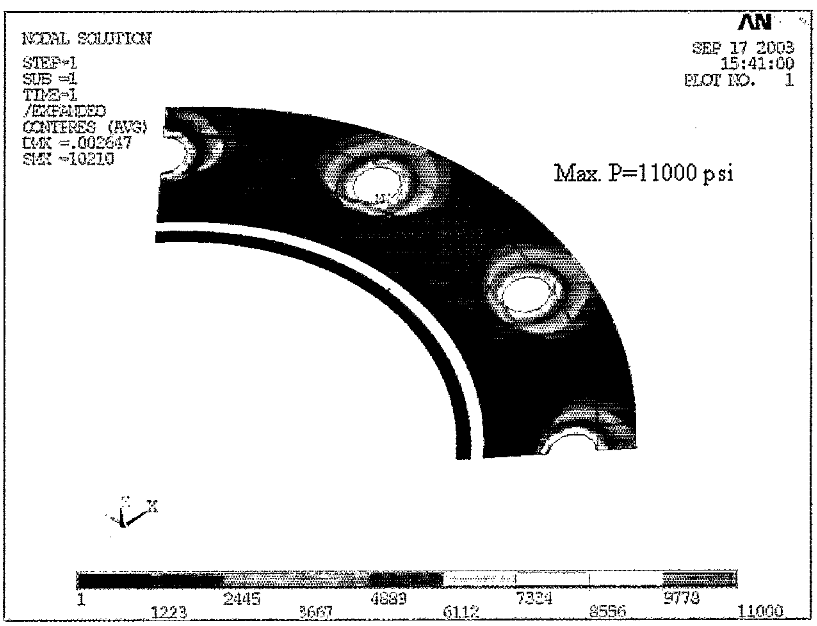


Fig. 10 Contact surface Gap, without Pressure

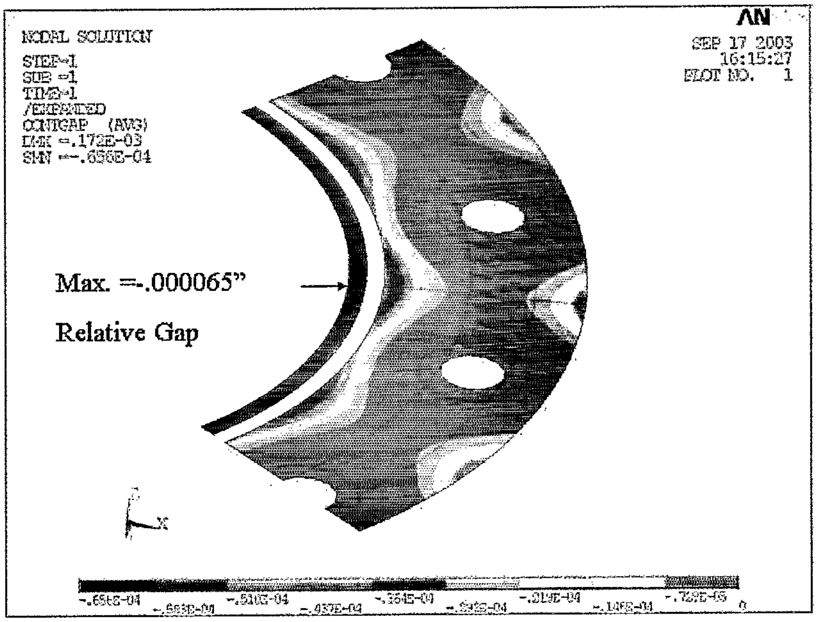


Fig. 11 Contact surface Gap, with 150 psi Pressure

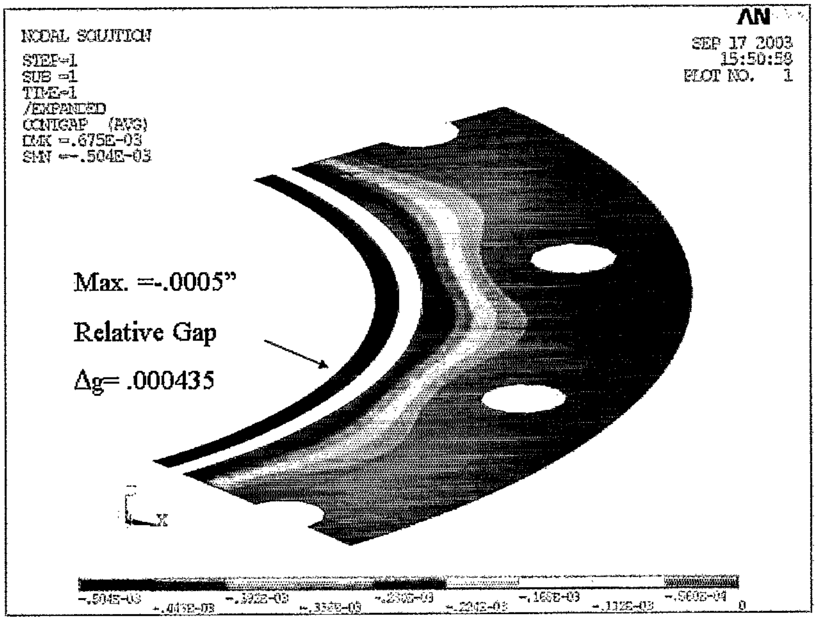


Fig. 12 Von Mises Stress in the Top Plate, Without Pressure

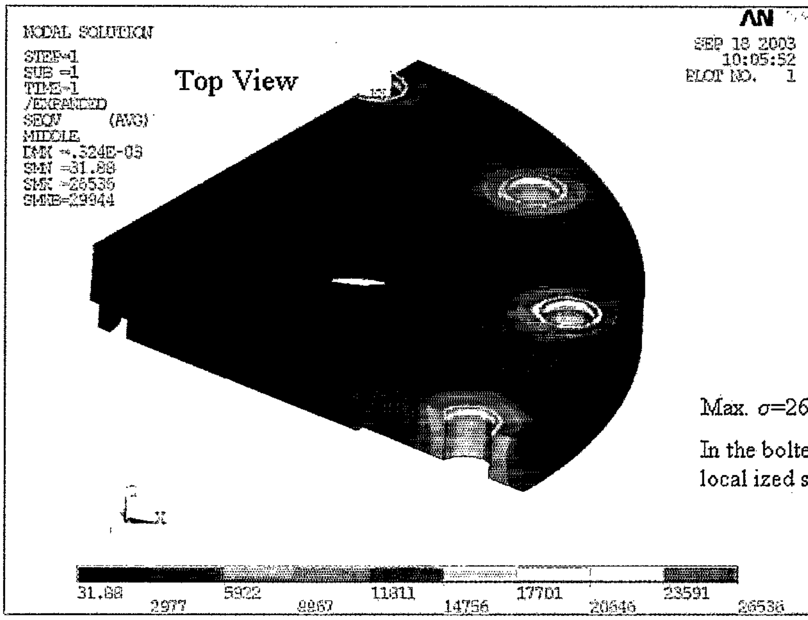


Fig. 13 Von Mises Stress in the Top Plate, Without Pressure

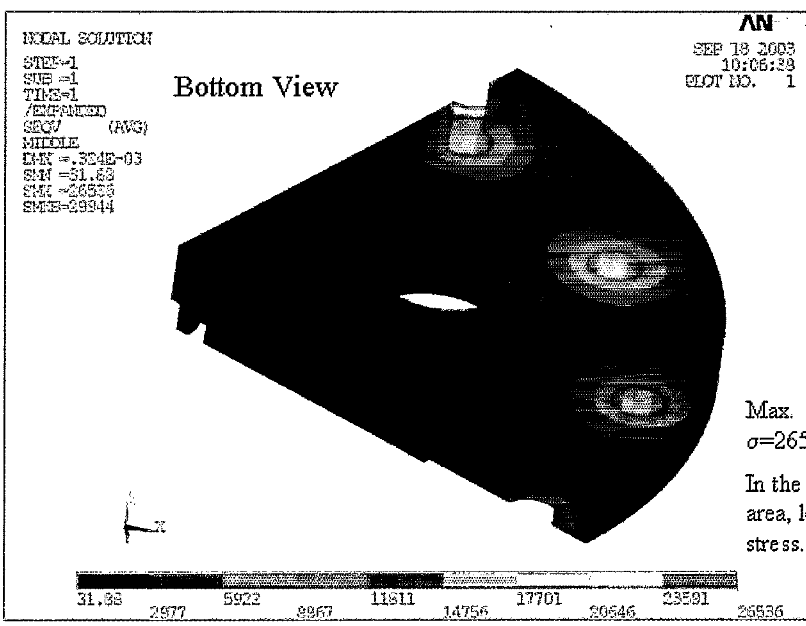


Fig. 14 Von Mises Stress in the Top Plate, With 150 psi Pressure

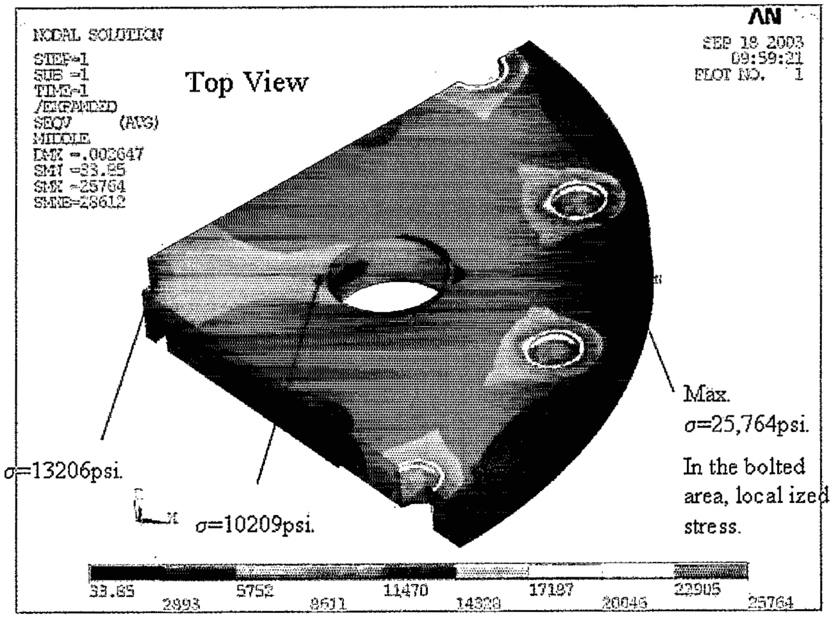
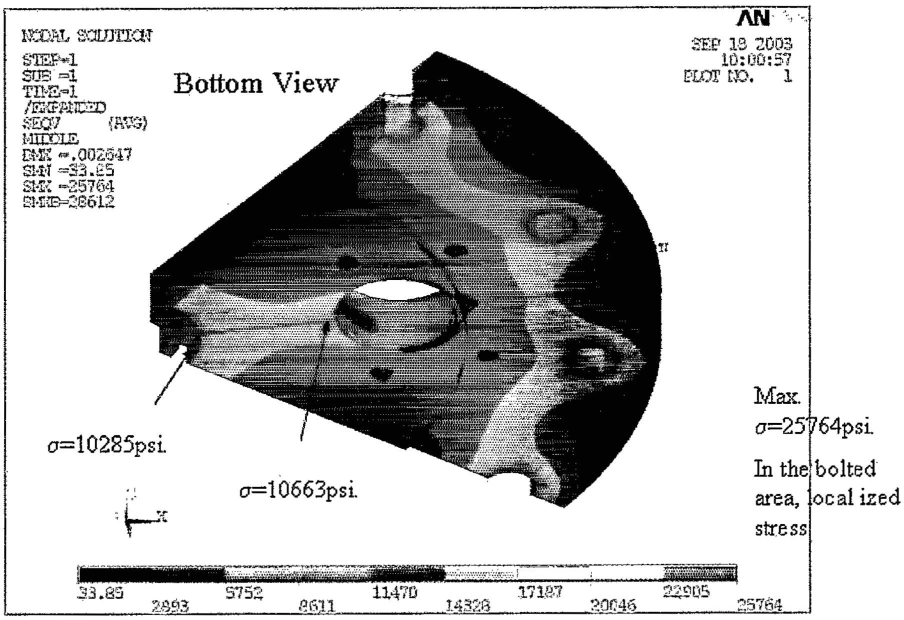


Fig. 15 Von Mises Stress in the Top Plate, With 150 psi Pressure



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managed by Brookhaven Science Associates
for the U.S. Department of Energy

Memo

date: *November 12, 2003* **SE88SR02**

to: *S. Kane*

from: *T. Monahan*

subject: ***Pressure Test for the E-Bubble Chamber***

The purpose of this memo is to document the E-Bubble Chamber passing the pressure test performed on October 27, 2003 in Building 835. This documentation is required by ES&H Standard 1.4.1 Pressurized Systems for Experimental Use. This memo documents the chamber description and pressure test methodology.

The Columbia E-Bubble chamber is a jacketed vessel. The inner chamber was designed to withstand 10 atmospheres of pressure. This chamber is jacketed, having a volume between the inner chamber and the cryostat of the device. The jacketed volume will be used to circulate cooling gas and maintain the temperature of the inner chamber. The jacketed volume was designed for a pressure differential of 20 psi.

The jacketed volume was instrumented with pressure gage, BNL ID# IN05169, and the inner chamber volume was instrumented with pressure gage, BNL ID# IN05030. Both had calibration dates of 10/24/2003.

The E-Bubble chamber was hydrostatically pressure tested on October 27, 2003. The test pressures were 150% of the design pressure, or 30 psi for the jacketed volume and 220 psi for the chamber volume. Because of the potential for different pressure differentials, the test was conducted as follows:

> Step 1 - Jacketed volume 30 psi, inner volume 0 psi. The pressure in the jacketed volume was valved-off.
> Step 2 - Jacketed volume 30 psi (closed), inner chamber volume 220 psi. Jacketed volume pressure was monitored for increase, demonstrating a leak between the inner and jacketed volumes.
> Step 3 - Jacketed volume pressure released, then closed. Pressure in jacketed volume was monitored for increase, demonstrating a leak between the inner and jacketed volumes. Inner chamber volume was monitored for pressure decrease, indicating a leak.

The exterior of the vessel was inspected throughout the test for evidence of water leakage, and none was observed. There was no change in the test pressures during the holding stages of the test.

Conclusion:

The chamber successfully passed the hydrostatic test and can be used within the design specifications cited earlier.

If you have any questions, I may be reached at extension 5937.

cc: J. Durnan

4. **Work with Physics ESR (Ron Gill) to develop plan/procedures for leaving cryostat unattended**

In discussions with Ron Gill, we were advised that his only recommendation would be to add 'Caution' signage to the experimental area indicating that the cryostat contains liquid when it is left unattended (for example overnight). We plan on taping off the area during these times also.

Attachments:

1. Copy of 14 May, 2003 e-mail describing interaction with Ron Gill (Physics ESR) and Tom Muller (Building 832 Manager).

Date: Wed, 14 May 2003 12:34:24 -0400
From: "Muller, Thomas R" <tmuller@bnl.gov>
To: 'Jeremy Dodd' <dodd@nevis.columbia.edu>
Cc: "Ron Gill (E-mail)" <gill@bnl.gov>, "Zarcone, Michael J" <zarcone@bnl.gov>, "Shapiro, Stephen" <shapiro@bnl.gov>
Subject: RE: Cryostat operation in 832

Hi Jeremy,

I agree with Ron's assessment concerning having good signs posted on the Cryostat and it's frame. This would indicate to any person in the Hi-Bay of the presence of LHe and LN2 in this apparatus, and any other pertinent information concerning the experiment in progress. We could include "Caution" indication and maybe tape off the area when left unattended, if you feel it would be appropriate.

See you soon,

Tom

-----Original Message-----
From: Jeremy Dodd [mailto:dodd@nevis.columbia.edu]
Sent: Wednesday, May 14, 2003 11:49 AM
To: Muller, Thomas R
Subject: Cryostat operation in 832

Dear Tom,

We are following up on a few items outstanding after the review of our experimental setup by the Cryogenic Safety Committee. One question they had for us is what procedures/precautions would be implemented when leaving the cryostat unattended overnight while containing LHe and LN2.

I discussed this yesterday with Ron Gill, Physics ES&H Coordinator, and he thinks that no special procedures should be needed, other than perhaps to add signage that the cryostat contains liquid. ODH is a non-issue.

I wanted to check that this seems correct to you, and ask whether there are any others points we should be aware of.

Thanks,
Jeremy

Jeremy Dodd	Nevis Laboratories
Tel: (914) 591 2821	Columbia University
Fax: (914) 591 8120	P.O. Box 137
e-mail: dodd@nevis.columbia.edu	Irvington
WWW: www.nevis.columbia.edu/~dodd	NY 10533

5. **Check whether the two pumping ports connected to the vapor-cooling circuit are vacuum-jacketed**

The two pumping ports are not vacuum-jacketed. The pump out flow is cold, but the maximum flow rate is very small (the pumping volume is just the volume between the double cylindrical walls, and only about 2.0 Kelvin maximum temperature differential in this annular region is needed). The LHe capillary feedline from the LHe reservoir into the cooling circuit has an OD of 0.093".

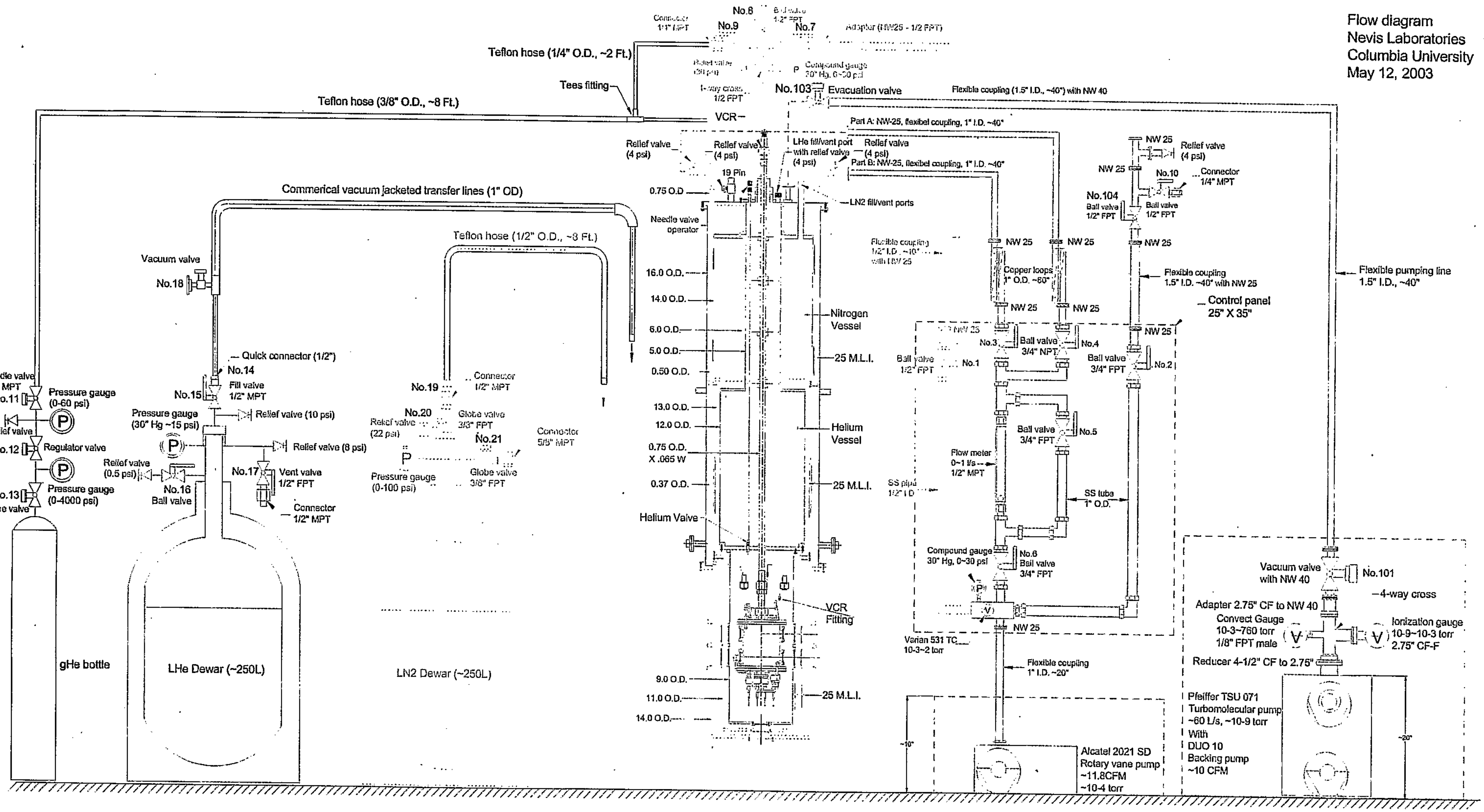
6. Make complete P&ID drawing for whole system

See Attachment 1.

Attachments:

1. Complete P&ID drawing of cryostat and pump/fill infrastructure. This file is also available at www.nevis.columbia.edu/~eBubble/review/revdocs.html.

Flow diagram
Nevis Laboratories
Columbia University
May 12, 2003



7. Determine pressure rating for the feedthroughs, and provide detail of the associated welds

Our June response to Richard Thomas is included below:

Two types of electrical feedthroughs are used in the eBubble chamber: ten high voltage, single-conductor feedthroughs and four low voltage, eight-conductor feedthroughs. Both are ceramic, and are produced by Ceramaseal. The single-conductor feedthroughs are rated at 1000 psig, while the eight-conductor feedthroughs are rated at 250 psig (see Attachment 1). The welds on the feedthroughs are fusion welds (see Attachment 2).

Attachments:
1. Feedthrough specifications from Ceramaseal for single-conductor feedthrough (part # 4275-15-W) and eight-conductor feedthrough (part # 9853-01-B).
2. AutoCad drawings showing weld details for both types of feedthrough.

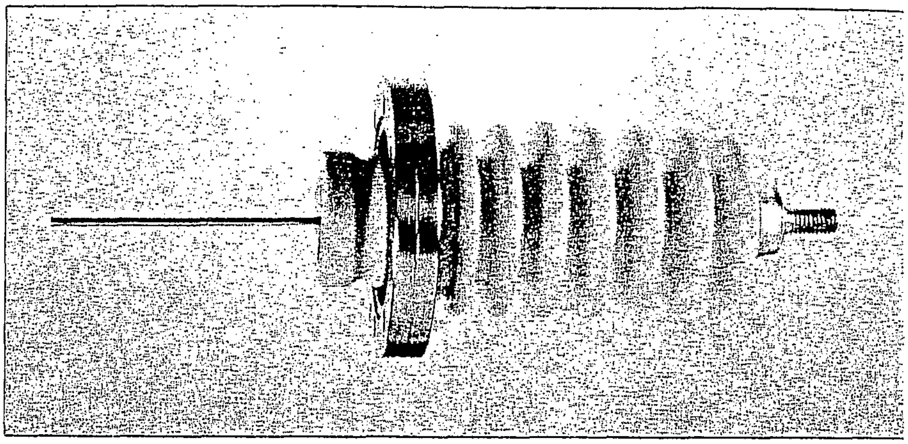
Since then, we have also provided S. Kane with documentation for the pressure rating of the corresponding (VCR) fittings. Steve has approved these.

INSTRUMENTATION FEEDTHROUGHS

Ceramaseal feedthroughs provide the solutions for applications requiring hermeticity and electrical isolation. In addition to remaining leak-free in high- and ultra-high vacuum, many of Ceramaseal's feedthroughs can accommodate:

- High temperatures
- Cryogenic temperatures
- High pressure
- Aggressive chemicals

These feedthroughs are commonly used in semiconductor processing equipment, accelerators, furnaces, instrumentation, and analytical test and measurement equipment.



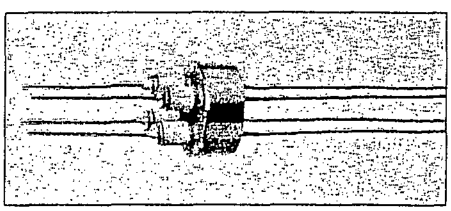
Ceramaseal's 60 KV high-voltage feedthrough. See page 28.

General Specifications

Voltage	Up to 100KV
Current	Up to 1000 amps
Bakeout Temperature	Up to 450°C
Operating Temperature	-269°C to 350°C
Vacuum Rating	Down to 10^{-10} torr
Pressure	Up to 5000 psig
Conductor	1 to 37
Corona-free designs available: pgs. 30-31	

The products in this section are used primarily to provide voltage or current into a high-vacuum or ultra-high-vacuum environment.

A feedthrough is basically defined by the requirements for installation, insulation and conductor material. The method of interconnection is flexible and left to the customer's discretion. A selection of push-on contacts can be found in the hardware section of this catalog. If you require a feedthrough with an interconnection device (plug) refer to the connector section of the catalog. For thermocouple feedthroughs and connectors refer to the section beginning on page 50.



4-pin UHV feedthrough. See page 18.

® Alumel is a registered trademark of Hoskins Mfg. Co.
® Conflat is a registered trademark of Varian Associates
® Constantan is a registered trademark of Wilbur B. Driver Co.
® Kovar is a registered trademark of Carpenter Technology.

Materials and Processes

Ceramaseal feedthroughs use only inorganic materials. The insulators are high-purity, high-strength, low-loss alumina ceramics. Metals include Kovar®, stainless steel, nickel, copper, nickel-iron alloys, cupro-nickel alloys, molybdenum, Alumel® and Constantan®.

Braze materials used are silver, copper, silver-copper or gold-copper alloys. Metallization processes include both refractory-metal and active-metal metallizations, dependent upon size, geometry and performance requirements for the seals. Ceramaseal uses advanced techniques for control of special and critical processes, including 100 percent helium leak testing and x-ray measurements for metallization control.

Mounting and Installation

Ceramaseal offers many installation options. Standard mountings include:

- Weld
- Braze
- Conflat® Flange
- Solder
- NPT Fitting
- ISO-NW Flange

For details on installing a Ceramaseal feedthrough, please refer to the Installation section, pages 163-168.

For push-on contacts refer to page 128.

For interconnections (plug) refer to the connector section on page 34.

Custom Design

Ceramaseal has more than 40 years experience in custom designs. Our sales and engineering staff will assist you with any application requiring simple catalog product modifications, as well as complex design challenges. Call us at 800-752-SEAL.

Selecting the Right Feedthrough

To select the right feedthrough for your applications, you should consider:

- Number of conductors
- Voltage and current rating requirements
- Installation
- Dimensional characteristics
- Other specific considerations, e.g., non-magnetic, cryogenic, etc.

To aid in the selection, we have arranged Ceramaseal's feedthroughs in this section as follows:

- Low-voltage feedthroughs (up to 12KV) pages 11-25.
- Water-cooled and RF feedthroughs page 15.
- High-voltage feedthroughs (20 to 100KV) pages 26-31.
- Corona-free feedthroughs pages 30-31 (see also information on corona-free units on page 26)
- No-conductor feedthroughs page 32.

Within each of these sections, products are arranged:

- by increasing number of conductors
- by increasing voltage and current ratings
- by type of mounting and installation

How to Order

A published price list is included with each catalog. Quantity discounts are available upon request. To order from this catalog, or for more information, please contact the sales representative closest to you (listing appears on inside back cover of this catalog) or Ceramaseal, P.O. Box 260, New Lebanon, N.Y. 12125; Tel: 800-752-SEAL; Fax: 518-794-8080

1 • CONDUCTOR

Weld Adapter
Bakeable to 450°C

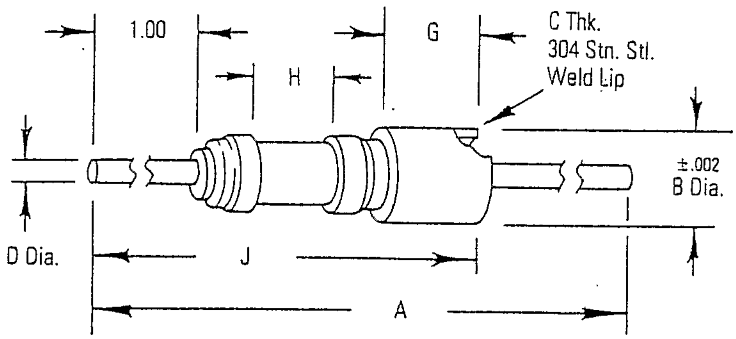


Figure 3

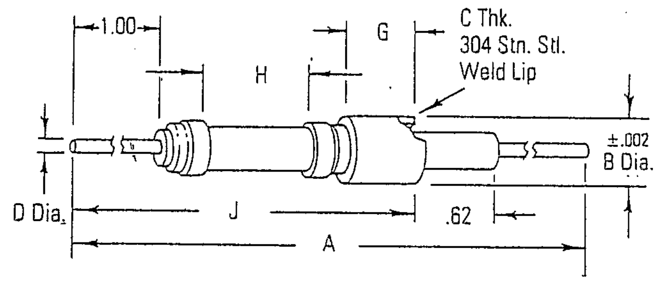


Figure 4

Ratings				Dimensions (inches)										
Voltage (DC)	Current (Amps)	External Pressure PSIG@ 20°C	Internal Pressure PSIG@ 20°C	A	B	C	D	G	H	J	Wall Thick-ness	Conductor Material	Fig. No.	Part Number
3KV	250	200	40	7.27	.747	.040	.375	.75	.60	3.14	–	Copper	3	2780-01-W
3KV	600	100	20	7.94	1.125	.040	.750	.75	.75	3.81	–	Copper	3	2781-01-W
3KV	–	200	40	7.27	.747	.040	.375	.75	.60	3.14	.032	Copper Tube	3	2780-02-W
3KV	–	100	20	7.94	1.125	.040	.750	.75	.75	3.81	.032	Copper Tube	3	2781-02-W
* 5KV	2	5000	1000	7.77	.435	.032	.094	.50	.25	2.21	–	304 SS	3	3887-68-W
* 5KV	5	5000	1000	7.77	.435	.032	.050	.50	.25	2.21	–	Nickel	3	3887-14-W
* 5KV	15	5000	1000	7.77	.435	.032	.094	.50	.25	2.21	–	Nickel	3	3887-51-W
* 5KV	30	5000	1000	7.77	.435	.032	.094	.50	.25	2.21	–	Copper	3	3887-12-W
* 5KV	40	2500	500	7.92	.495	.029	.154	.50	.32	2.42	–	Nickel	3	6514-02-W
* 5KV	60	2500	500	7.92	.495	.029	.154	.50	.32	2.42	–	Copper	3	6514-01-W
* 5KV	–	5000	1000	4.05	.435	.032	.094	.50	.25	2.21	.020	Nickel Tube	3	3887-11-W
* 12KV	7.5	500	150	7.26	.622	.040	.250	.75	.66	3.13	–	304 SS	3	2779-14-W
* 12KV	15	5000	1000	7.77	.435	.030	.094	.50	.69	2.63	–	Nickel	4	4275-15-W
* 12KV	30	5000	1000	7.77	.435	.030	.094	.50	.69	2.63	–	Copper	4	4275-14-W
* 12KV	75	500	150	7.26	.622	.040	.250	.75	.66	3.13	–	Nickel	3	2779-07-W
* 12KV	150	500	150	7.26	.622	.040	.250	.75	.66	3.13	–	Copper	3	2779-01-W
* 12KV	–	500	150	7.26	.622	.040	.250	.75	.66	3.13	.035	304 SS Tube	3	2779-06-W
* 12KV	–	500	150	7.26	.622	.040	.250	.75	.66	3.13	.032	Nickel Tube	3	2779-08-W
* 12KV	–	500	150	7.26	.622	.040	.250	.75	.66	3.13	.032	Copper Tube	3	2779-02-W

$25/each

Kevin!

in stock

All dimensions are in inches. * Suitable for use in cryogenics.

Products in this catalog are vacuum-rated to 10^{-10} torr unless otherwise noted. For pressure rating, see each table.

8 • CONDUCTOR

Weld, Braze or Solder
Bakeable to 450°C

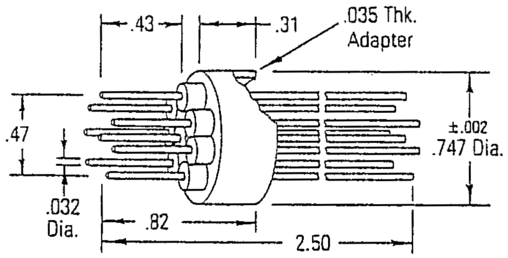


Figure 28

Ratings

Voltage (DC)	Current (Amps)	External Pressure PSIG@ 20°C	Internal Pressure PSIG@ 20°C	Conductor Material	Fig. No.	Part Number	Suggest. Attach-ment	Adapter
500V	2	250	250	Nickel	28	9294-01-W	Weld,	304 SS
500V	2	250	250	Constantan®	28	9853-01-B	Braze or Solder	CuNi Alloy

want these →

Conflat® Mounting
Bakeable to 450°C

ISO-NW flange on request

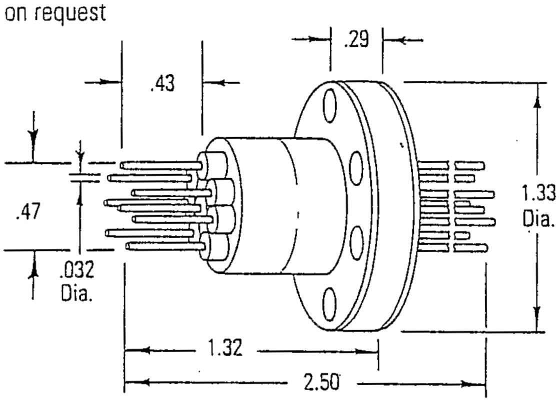


Figure 29

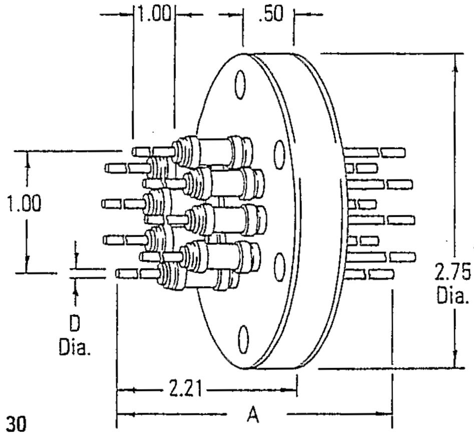


Figure 30

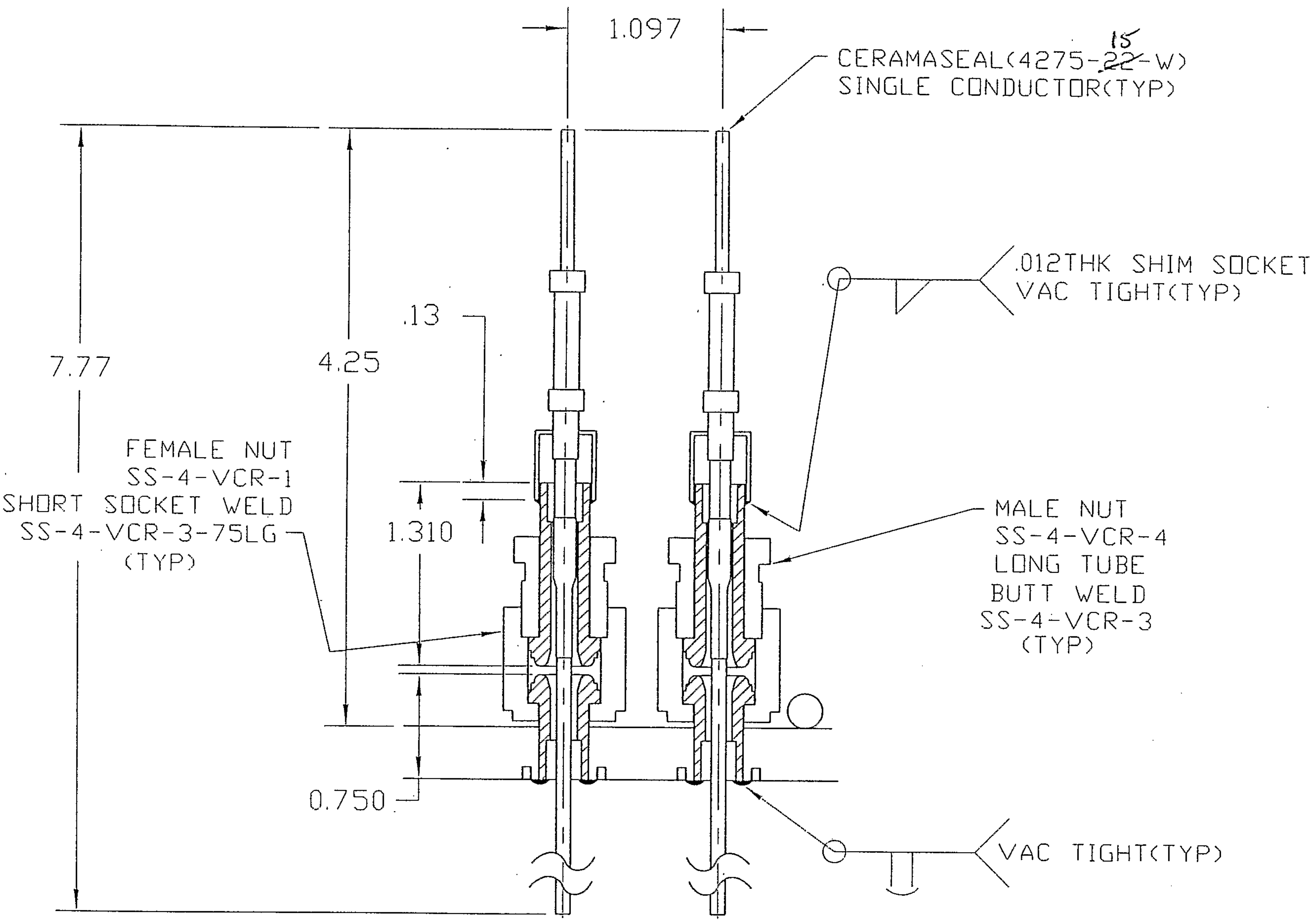
Ratings **Dimensions (inches)**

Voltage (DC)	Current (Amps)	External Pressure PSIG@ 20°C	Internal Pressure PSIG@ 20°C	A	D	Wall Thick-ness	Conductor Material	Fig. No.	Part Number	Flange
500V	2	250	250	–	–	–	Nickel	29	9340-01-CF	304 SS
500V	2	250	250	–	–	–	Constantan®	29	9340-03-CF	304 SS
5KV	5	250	250	7.77	.050	–	Nickel	30	6712-01-CF	–
5KV	–	250	250	3.15	.050	.005	Ni Tube	30	6712-05-CF	–
5KV	15	250	250	7.77	.094	–	Copper	30	6712-02-CF	–
5KV	30	250	250	7.77	.094	–	Nickel	30	6712-03-CF	–

ordered these →

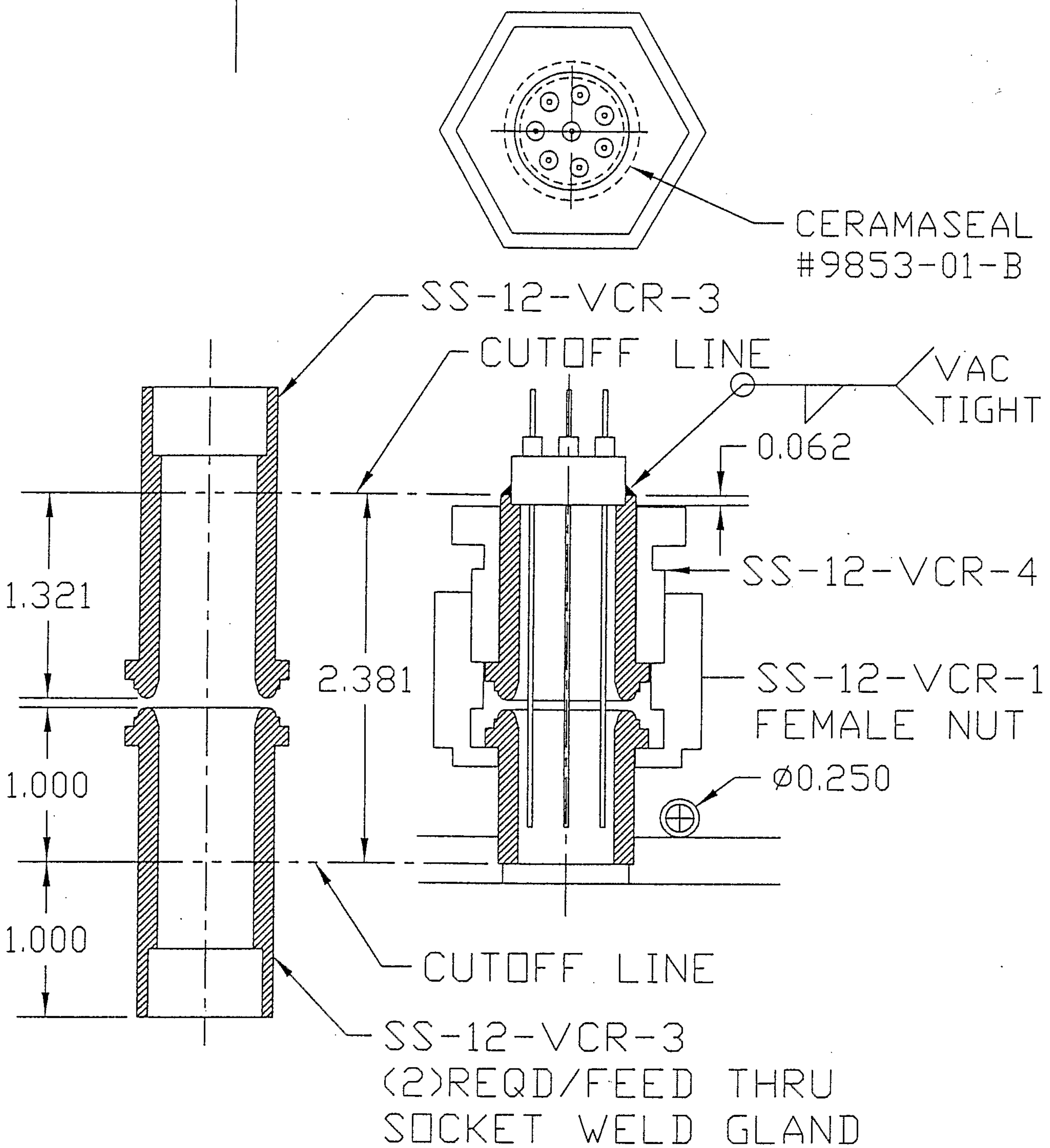
All dimensions are in inches. Suitable for use in cryogenics.

Products in this catalog are vacuum-rated to 10^{-10} torr unless otherwise noted. For pressure rating, see each table.



NEXT ASSY	SA-3-4-F	SCALE	FULL	SECTION	XXX
TITLE	HV FEED THRU'S	XXX			SK-3-I-G

REVISIONS				
ZONE	REV	DESCRIPTION	DATE	APPROVED



COLUMBIA UNIVERSITY
NEVIS LABS

LOW VOLTAGE
FEED THROUGH

SIZE	FSCM NO.	DWG NO.	REV
A		SK-1-1-B	A

SCALE FULL | SHEET

8. **Provide more detail on the welds of the eBubble chamber, including providing a complete set of drawings**

A complete set of AutoCad drawings of the eBubble chamber, designed by retired BNL engineer L. Addessi, is included (Attachment 1). Drawings WA-1-4-E, WD-1-4-E and WD-2-4-E show details of the welds on the chamber body, while drawings SK-3-1-G and SK-1-1-B show details of the welds on the feedthroughs (both HV and LV/signal).

On the chamber body (WA-1-4-E), all welds are .1" fillet welds using 316L SS filler rod, with the exception of two fusion welds where the SS elbows and tubes (item 5 and 6) of the LHe cooling circuit are joined. The welds on the feedthroughs are fusion welds.

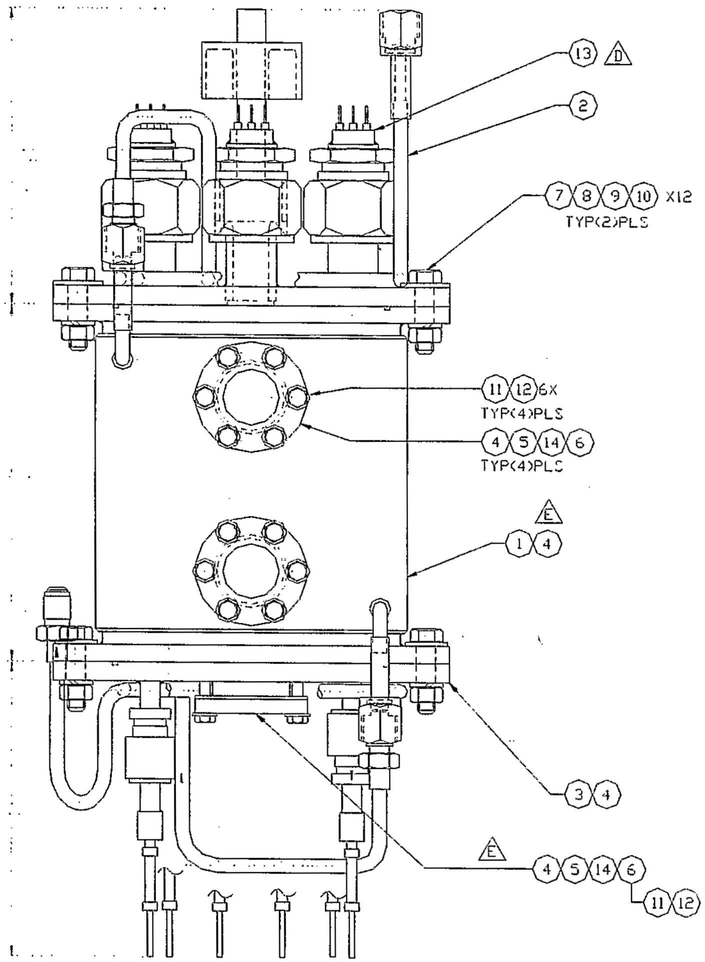
Attachments:

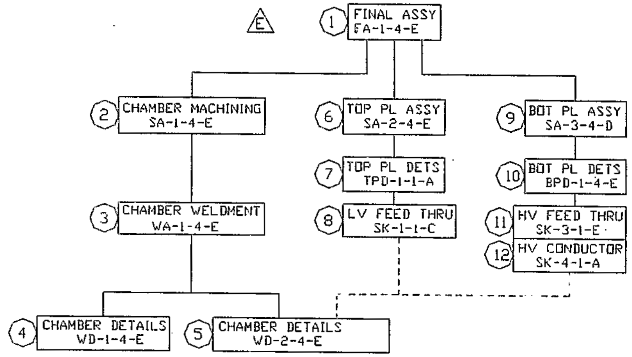
1. Complete set of AutoCad drawings for the eBubble chamber. These files are also available at www.nevis.columbia.edu/~eBubble/review/revdocs.html.

Nevis/BNL eBubble Chamber Drawings

Final Chamber Assembly	FA-1-4-E
Machining Assembly	SA-1-4-E
Welding and Leak Check	WA-1-4-E
Weldment Detail (1 of 2)	WD-1-4-E
Weldment Detail (2 of 2)	WD-2-4-E
Top Plate Detail and Assembly	SA-2-4-E
Bottom Plate Detail	BPD-1-4-E
Bottom Plate Assembly	SA-3-4-F
HV Feedthroughs	SK-3-1-G
LV (Signal) Feedthroughs	SK-1-1-B

REV	DESCRIPTION	DATE	APPROVED
D	ADDED ITEM 13	4/10/01	
E	REVISED PICTURE,CHANGED BOT WINDOW	5/1/01	





ITEM	QTY	DESCRIPTION	MATERIAL/MFG
X	X	X	X
14	5	PAD	SA-3-4-D(ITEM 15)
13	4	LOW VOLTAGE FEED THROUGH ASSY	SK-1-1-C
12	30	WASHER,FLAT #10	STL OR SS
11	30	SCR,HEX HD #10-32NF X .75LG	STL OR SS
10	24	NUT,HEX 5/16-18NC	STL OR SS
9	24	WASHER,LOCK 5/16	STL OR SS
8	24	WASHER,FLAT 5/16(.75 OD)	STL OR SS
7	24	SCR,HEX HD 5/16-18NC X 1.25LG	STL OR SS
6	5	CLAMP,WINDOW	SA-3-4-D(ITEM 14)
5	5	WINDOW	OPTICAL GLASS(SUPPLIED BY NEVIS)
4	AR	WIRE,INDIUM	Ø.095
3	1	BOTTOM PLATE,DETAILS & ASSEMBLY	SA-3-4-D
2	1	TOP PLATE,DETAILS & ASSEMBLY	SA-2-4-E
1	1	CHAMBER,MACHINE ASSEMBLY	SA-1-4-E

EXPERIMENTER	
CONSULTANT	
DESIGN ENGR.	L.J. ADDESSI
APPROVED	
DATE	3/2/01

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NEVIS LABS

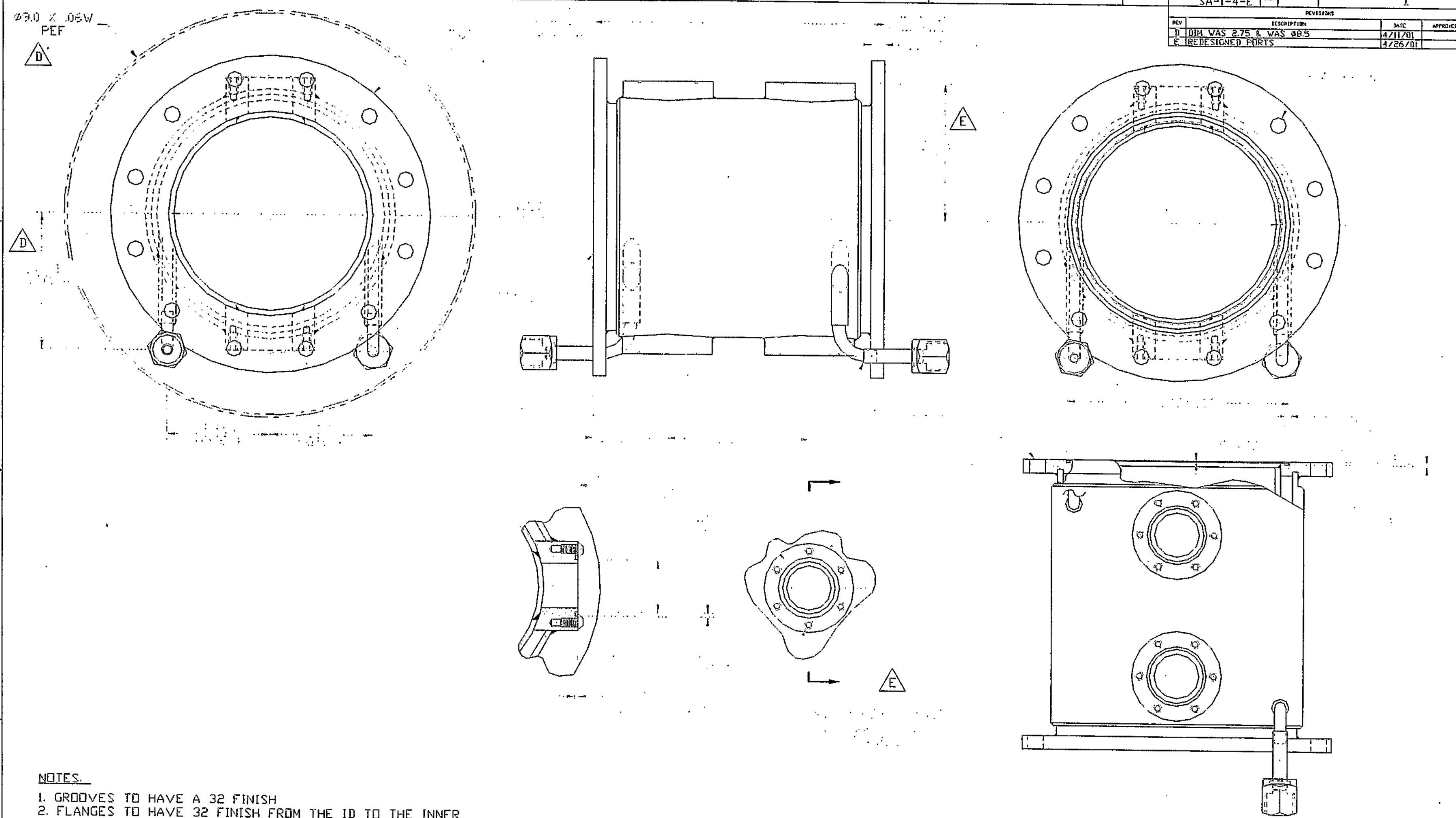
eCHAMBER

FINAL CHAMBER ASSY FA-1-4-E

RELEASED-4/3/01

DWG NO. SA-1-4-E SHT.

REVISIONS			
REV	DESCRIPTION	DATE	APPROVED
D	DIM WAS 2.75 & WAS Ø8.5	4/11/01	
E	REDESIGNED PORTS	4/26/01	



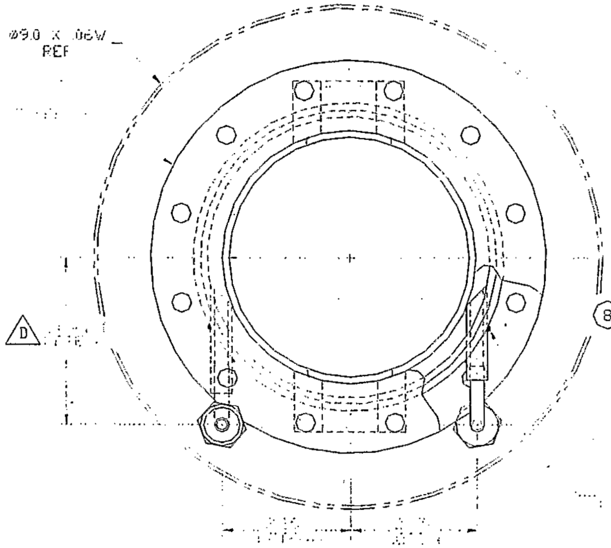
NOTES:

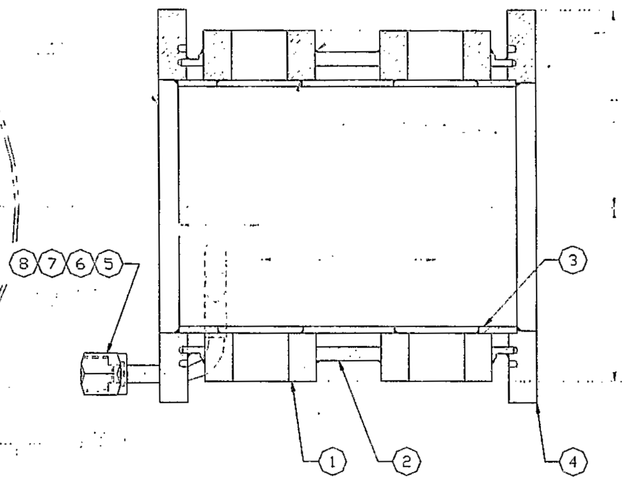
1. GROOVES TO HAVE A 32 FINISH
2. FLANGES TO HAVE 32 FINISH FROM THE ID TO THE INNER EDGE OF THE BOLT HOLES
3. WELD AFTER MACHINING
4. MATE WITH TOP ASSY(SA-2-4-D) & BOT ASSY(SA-3-4-D) TO POSITION FOR WELDING
5. WELDS TO BE VACUUM TIGHT

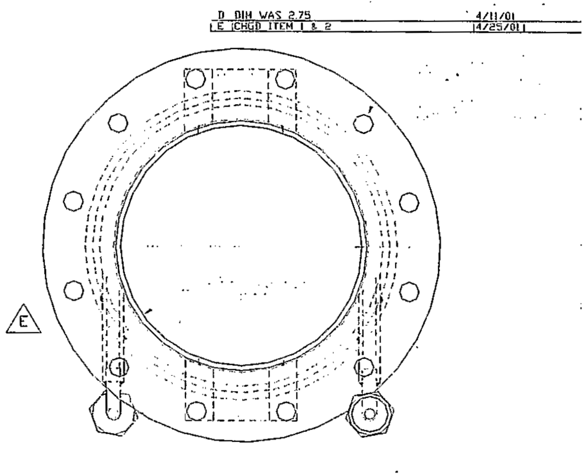
X	X	X	X
ITEM	QTY	DESCRIPTION	MATERIAL/MFG

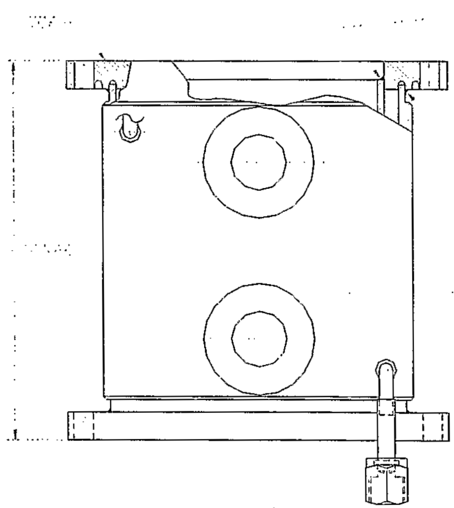
EXPERIMENTER		COLUMBIA UNIVERSITY NEVIS LABS
CONSULTANT		
DESIGN ENGR.	L.J. ADDESSI	eCHAMBER
APPROVED		
DATE 4/26/01		MACHINING ASSEMBLY SA-1-4-E

D	DIM WAS 2.75	4/11/01
E	CHGD ITEM 1 & 2	4/25/01









WELDING & LEAK CHECK PROCEDURE

1. TACK WELD FLANGES(ITEM 4) TO INNER & OUTER CYLINDERS
2. INSERT ITEM 1 & CHECK OVERALL DIMENSION & TACK WELD
3. TACK WELD BOTTOM FLANGE(ITEM 4) TO CYLINDERS. CHECK OVERALL LENGTH & ALIGNMENT OF FLANGES BEFORE WELDING FLANGES & CYLINDERS.
4. WELD He SUPPLY & RETURN PORTS ITEMS 1,5 & 6 - USE ITEMS 7&8 TO POSITION ITEMS 5 & 6 - ITEMS 7&8 TO BE WELDED AFTER MACHINING - SEE (SA-1-4-E)
5. LEAK CHECK INNER & OUTER CYLINDER WALL WELDS USING BLANKOFF FLANGES(ITEM 8) & He SUPPLY & RETURN PORTS
6. HOLES MAY BE SPOT DRILLED FROM BLANKOFF FLANGES SEE DWG WD-2-4-E
7. WELD TO BE VACUUM TIGHT

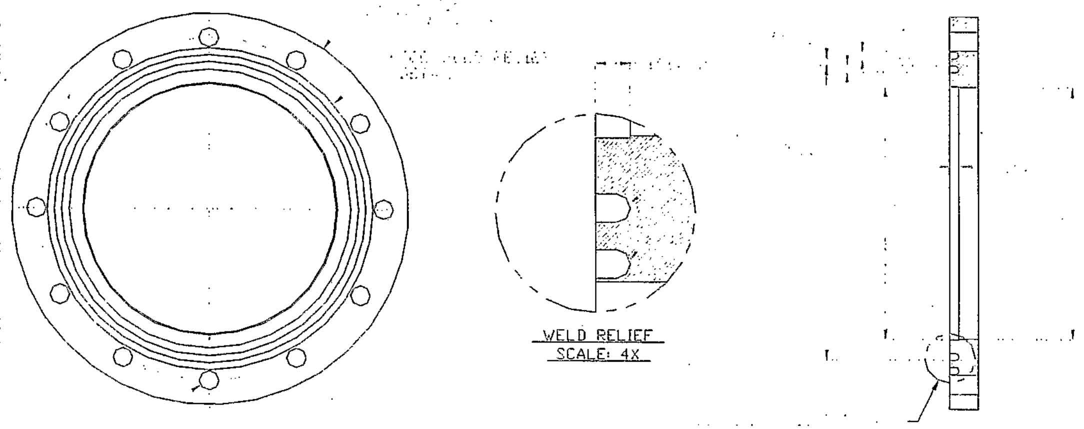
SEE DWG WD-1 & 2-4-E FOR DETAILS

ITEM	QTY	DESCRIPTION	MATERIAL/MFG
9	X	X	X
8	2	GLAND,SOCKET WELD	CAJON #SS-4-VCR-3
7	2	NUT,FEMALE	CAJON #SS-4-VCR-1
6	2	ELBOW,90 304SS	TRULY TUBULAR #90MM4
5	2	TUBE, .375 OD X .065W X 3" 304SS	TUBE SALES
4	2	FLANGE,SS304 PLATE .5THK X 7.0 DIA	TUBE SALES
3	1	TUBE 4.50 OD X .12W X 6.00 304SS	TUBESALES
2	1	TUBE 5.50 OD X .25W X 6.00 304SS	TUBESALES
1	4	PORT,HOLLOW BAR SS304	1.968 OD(50mm) X .492 W(12.5mm) X 1.5LG(38mm)

EXPERIMENTER		COLUMBIA UNIVERSITY
CONSULTANT		NEVIS LABS
DESIGN ENGR.	L.J. ADDESSI	eCHAMBER
DATE 4/25/01	APPROVED	WELDMENT ASSEMBLY | WA-1-4-E

WD-1-4-E

E REDESIGNED ITEM(1)TEXT 4/25/01 X

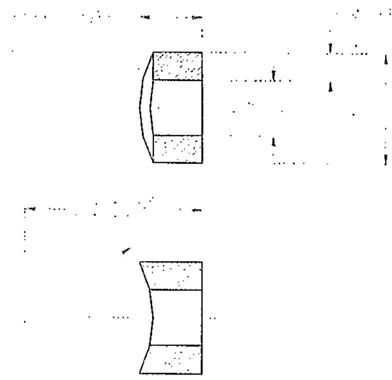


WELD RELIEF
SCALE: 4X

TOP FLANGE (5)

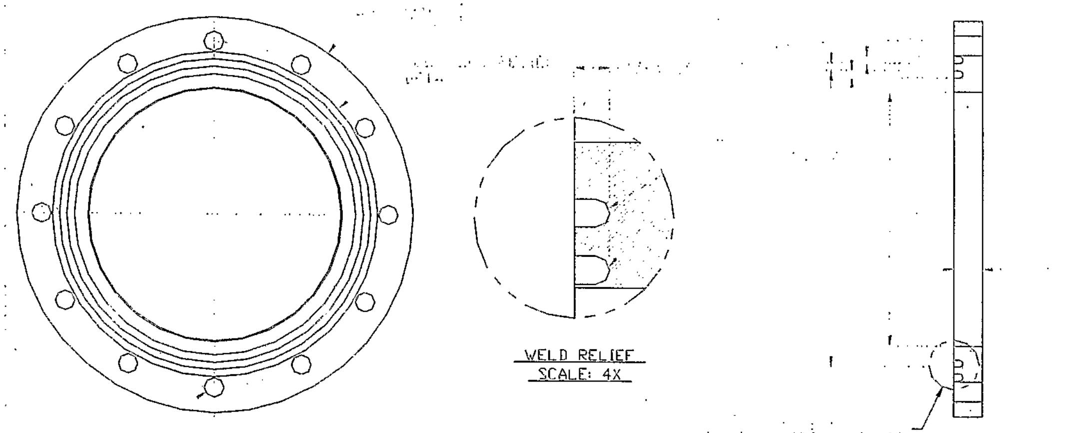
MATERIAL: SEE WELDMENT ASSY(WA-1-4-E)

NOTE: 1) HOLES MAY BE SPOT DRILLED FROM ITEM 10/11 (WD-2-4-E)



PORT (1) E

MATERIAL: SEE WELDMENT ASSY(WA-1-4-E) REQD: 4

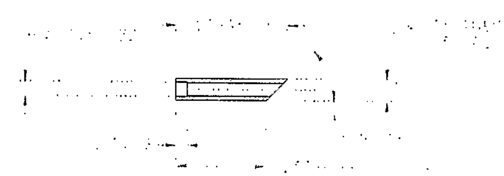


WELD RELIEF
SCALE: 4X

BOTTOM FLANGE (5)

MATERIAL: SEE WELDMENT ASSY(WA-1-4-E)

NOTE: 1) HOLES MAY BE SPOT DRILLED FROM ITEM 10/11 (WD-2-4-E)



TUBE (9)

MATERIAL: SEE WELDMENT ASSY(WA-1-4-E)

REQD: 2

	NAME	DATE
EXPERIMENTER		
CONSULTANT		
DESIGN ENGR	L.J. ADDESSI	4/25/01
APPROVED		

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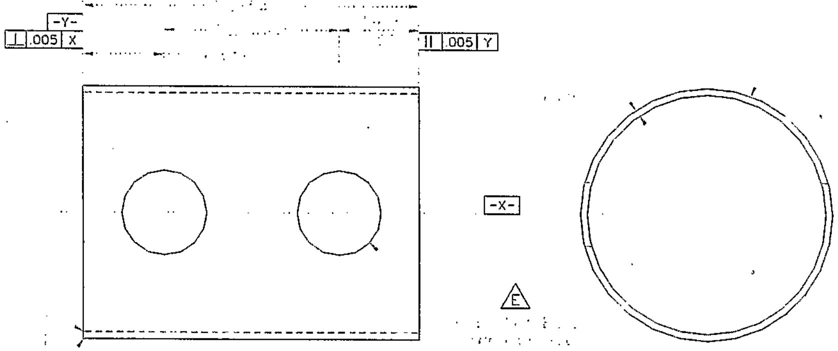
NEVIS LABS

eCHAMBER

WELDMENT DETAILS | WD-1-4-E

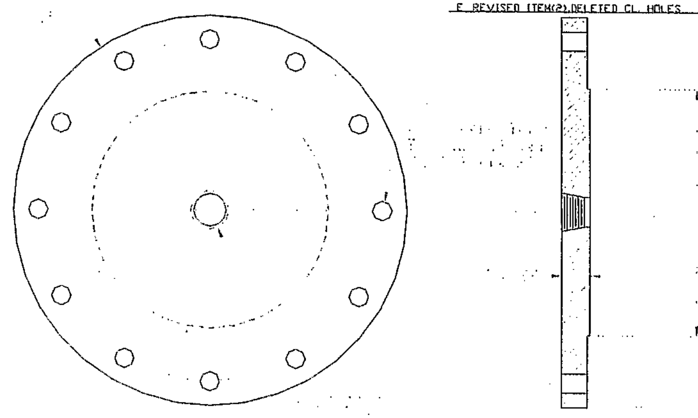
WD-2-4-E

E REVISED ITEM(2),DELETED CL HOLES 4/25/01



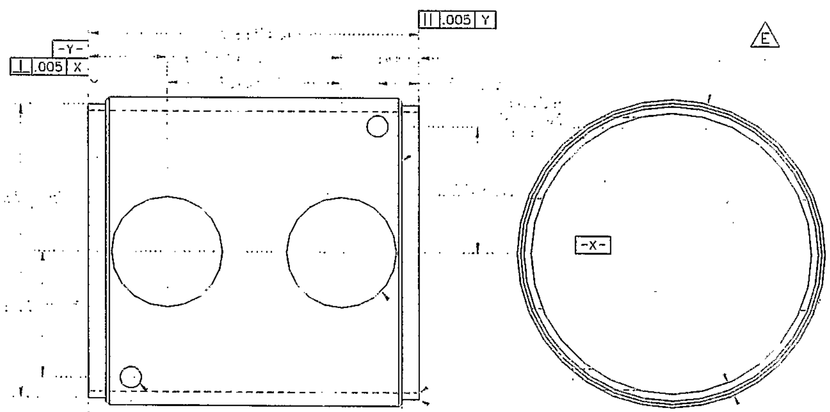
TUBE (3)

MATERIAL: SEE WELDMENT ASSY(WA-1-4-E)



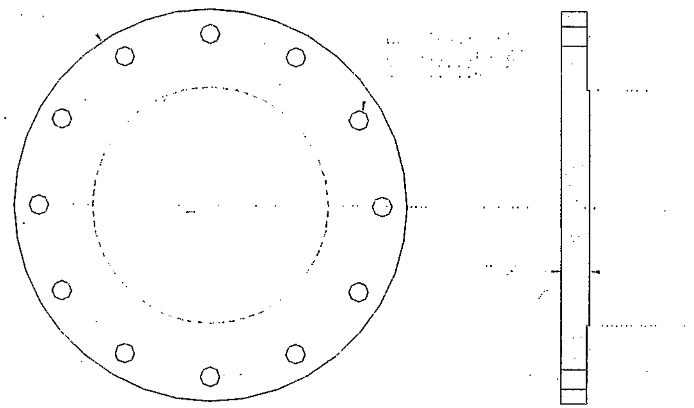
FLANGE,BOTTOM BLANKOFF (11)

MATERIAL: .50THK X 7.00DIA SS304



TUBE (2)

MATERIAL: SEE WELDMENT ASSY(WA-1-4-E)



FLANGE,TOP BLANKOFF (10)

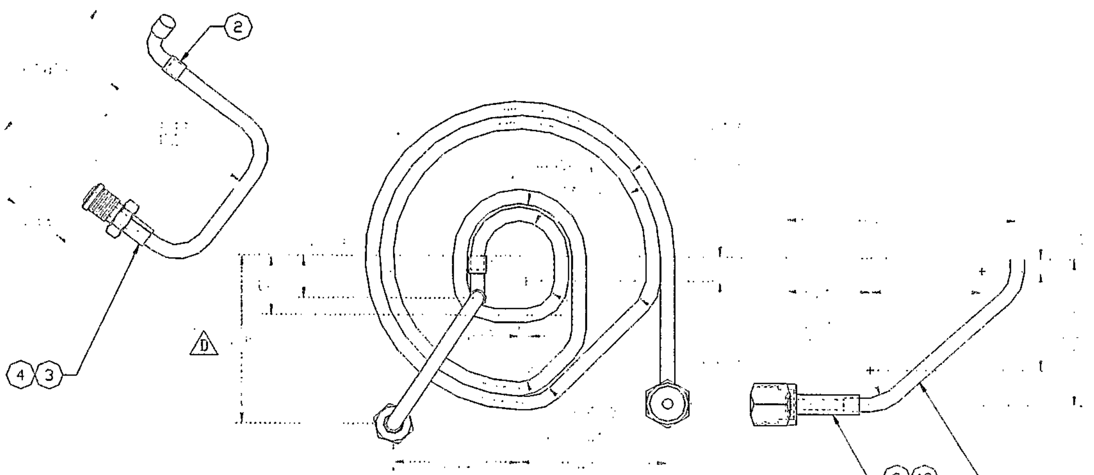
MATERIAL: .50THK X 7.00DIA SS304

	NAME	DATE	
EXPERIMENTER			COLUMBIA UNIVERSITY
CONSULTANT			NEVIS LABS
DESIGN ENGR.	L.J. ADDESSI	4/25/01	eCHAMBER
APPROVED			WELDMENT DETAILS / WD-2-4-E

RELEASED 4-5-01

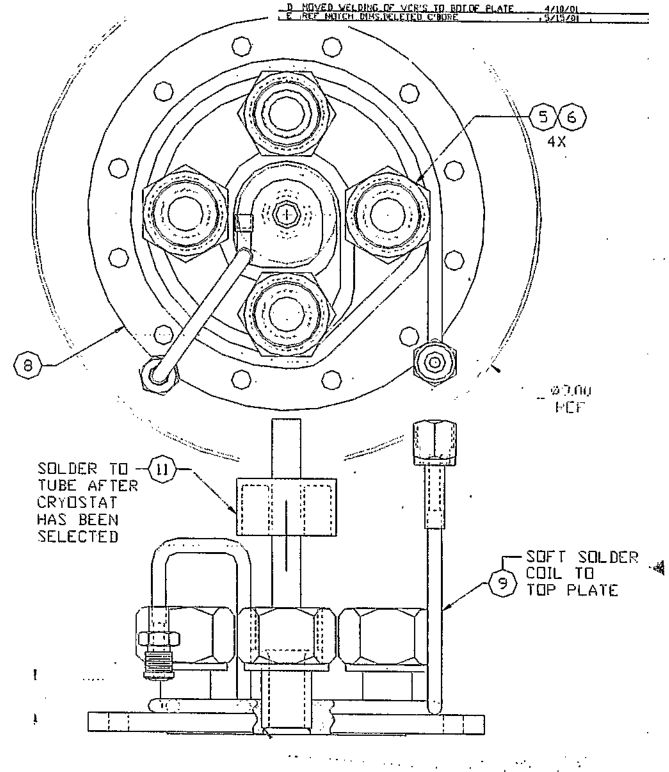
SA-2-4-E

D	MOVED WELDING OF VCR'S TO BOT OF PLATE	4/10/01
E	REF NOTCH DIMS, DELETED C'BORE	5/15/01

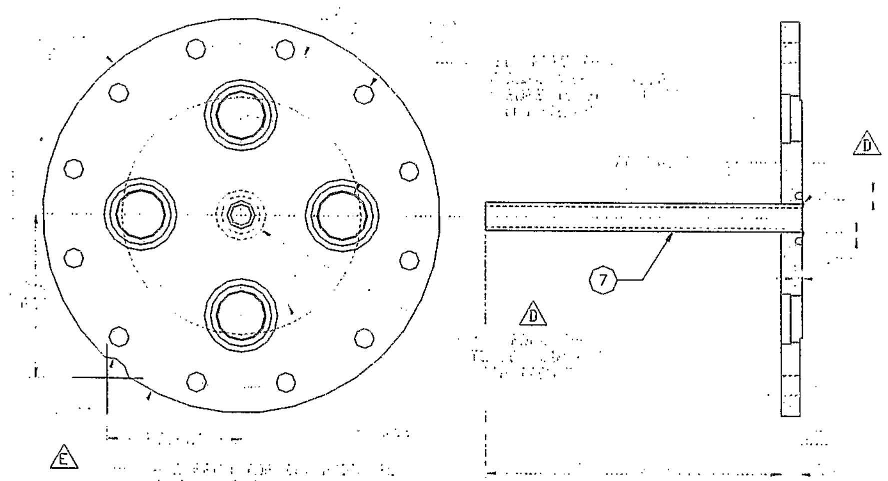


NOTE
SILVER SOLDER FITTINGS TO TUBING

COIL DETAIL 9



TOP PLATE ASSEMBLY



TOP PLATE DETAIL 8

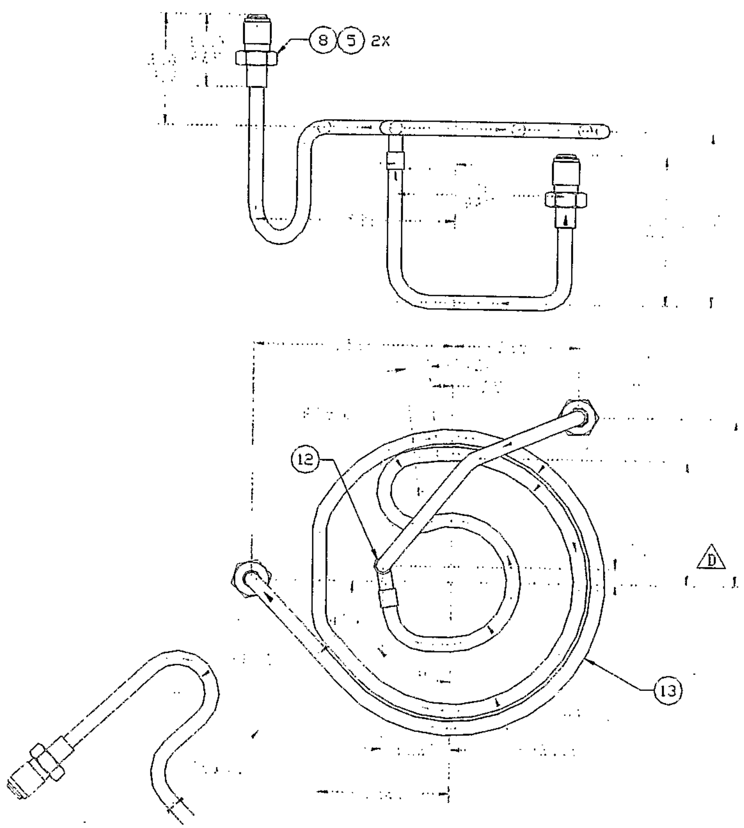
ITEM	QTY	DESCRIPTION	MATERIAL/MFG
11	1	COLD SINK DETAIL	TPD-1-1-A
10	1	GLAND,SOCKET WELD	CAJON #SS-8-VCR-3
9	1	COIL DETAIL	THIS DWG
8	1	TOP PLATE DETAIL	THIS DWG & SEE WD-2-4-D (ITEM 10)
7	1	TUBE, .50 OD X .065W X 6.0LG	TUBE SALES
6	4	NUT,FEMALE	CAJON #SS-12-VCR-1
5	4	GLAND,MODIFIED (CAJON SS-12-VCR-3)	DWG #SK1-LV FEED THRU
4	1	NUT,MALE	CAJON #SS-4-VCR-4
3	2	GLAND,SOCKET WELD	CAJON #SS-4-VCR-3(SEE SK-1-1-C)
2	1	ELBOW,90FF 304SS	TRULY TUBULAR #90FF4
1	AR	TUBING,1/4 OD X .03W COPPER	REFRIGERATION TUBING(SOFT)

	NAME	DATE
EXPERIMENTER		
CONSULTANT		
DESIGN ENGR.	L.J. ADDESSI	4/27/01
APPROVED		

COLUMBIA UNIVERSITY
NEVIS LABS
eCHAMBER
TOP PL. DET. & ASSY | SA-2-4-E
RELEASED-4/3/01

BPD-1-4-E

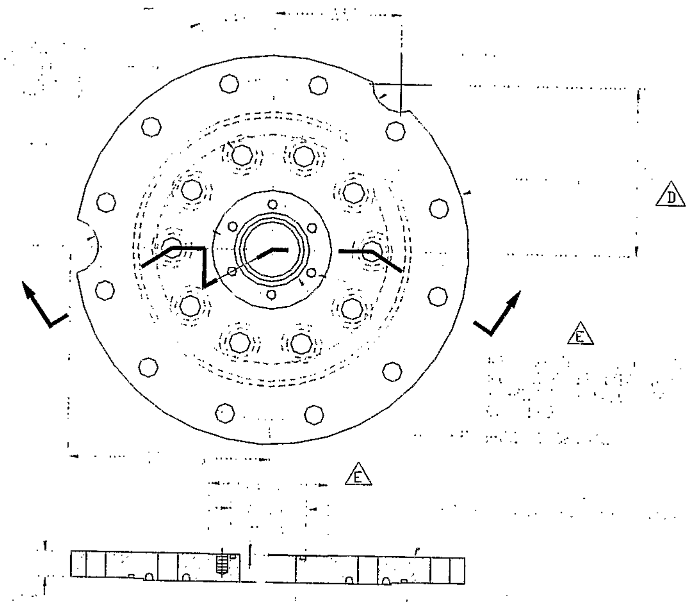
D	DIM WAS 2.75	4/11/01
E	ADDED GROOVE & MTG HOLES/WINDOW	4/28/01

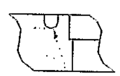


COIL DETAIL & ASSEMBLY (1)

NOTE: WELD FITTINGS & SILVER SOLDER TUBING TO FITTINGS & ASSEMBLY TO BE VACUUMN TIGHT

WHERE NOT NOTED , MIN BENDING RADIUS TO BE .5





TYPICAL WELD RELIEF
SCALE: TWICE

BOTTOM PLATE DETAIL (2)

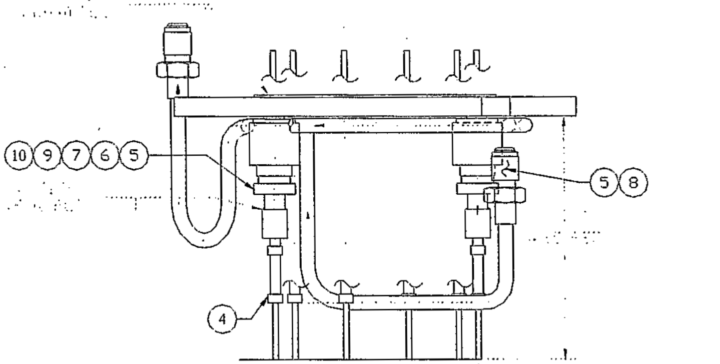
GROOVE DETAIL
SCALE: 4X

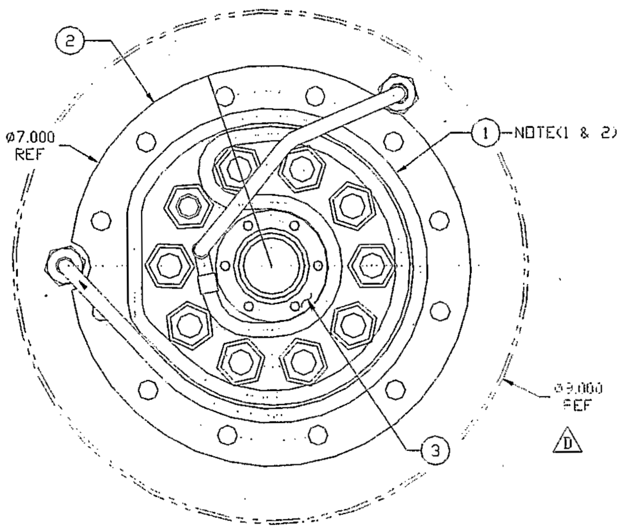
NOTE BREAK ALL SHARP CORNERS & INSIDE RADII TO BE .02R UNLESS OTHERWISE NOTED

	NAME	DATE	
EXPERIMENTER			COLUMBIA UNIVERSITY NEVIS LABS
CONSULTANT			
DESIGN ENGR.	L.J. ADDESSI	4/28/01	eCHAMBER
APPROVED			
			BOT PLATE DETAIL — BPD-1-4-E

RELEASED-4/3/01

D	REVISED PIC. FOR DETS.ADDED ITEM 15	4/27/01
F	REVISED FOR HV FEED THRU	8/21/01

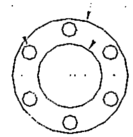




BOTTOM PLATE ASSY

NOTE:

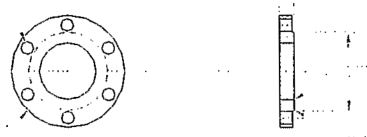
1. LEAK CHECK VCR WELDS & PORT BEFORE SOLERING COIL TO TOP PLATE
2. LEAK CHECK COIL ASSY BEFORE SOLDERING TO TOP PLATE



PAD (15)

MAT: .06THK TEFLON

NOTE: USED ON MAIN ASSEMBLY FA-1-4-D



WINDOW CLAMP (14)
REQD: 5

NOTE:

1. BREAK ALL SHARP EDGES
2. USED ON MAIN ASSEMBLY FA-1-4-D

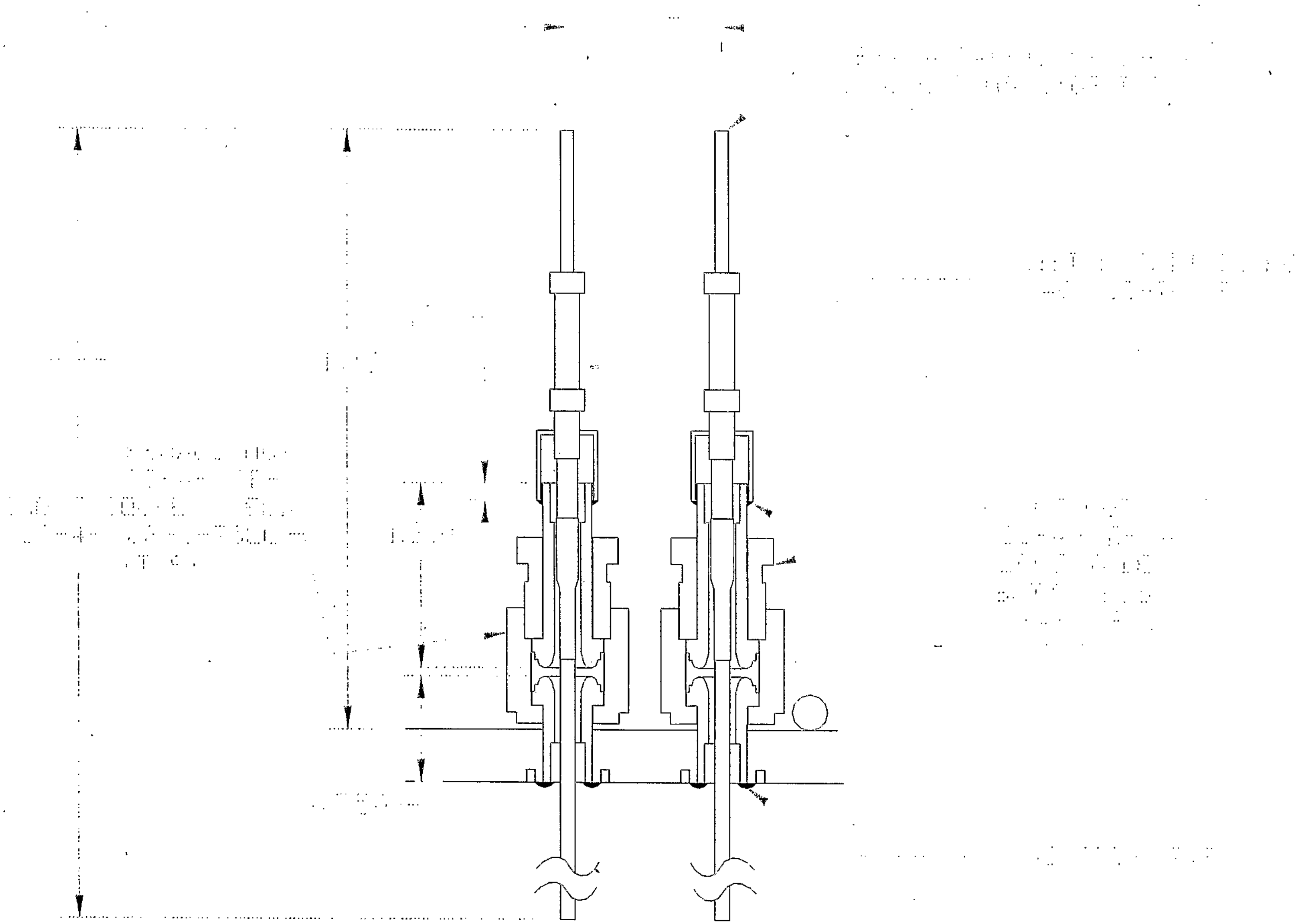
ITEM	QTY	DESCRIPTION	MATERIAL/MFG
15	5	PAD(THIS DWG)	TEFLON .06THK
14	5	WINDOW CLAMP DETAIL(THIS DWG)	HOLLOW BAR 1.968"OD X .492W X 3.0LG SS304
13	AR	TUBING,1/4 OD X .03W COPPER	REFRIGERATION TUBING(SOFT)
12	1	ELBOW,90FF4 304SS	TRULY TUBULAR #90FF4
11	X	X	X
10	10	GLAND,SHORT SOCKET WELD	CAJON # SS-4-VCR-3-75LG (SEE SK-3-1-G)
9	-	X	X
8	12	GLAND, SOCKET WELD	CAJON #SS-4-VCR-3(SEE SK-3-1-G & BPD-1-4-E
7	10	GASKET,COPPER	D19-M-6178-1
6	10	NUT,FEMALE	CAJON #SS-4-VCR-1
5	12	NUT,MALE	CAJON #SS-4-VCR-4
4	10	FEED THRU ,SINGLE CONDUCTOR	CERAMASEAL #4275-22-W (SEE SK-3-1-G)
3	1	PORT DETAIL (THIS DWG)	HOLLOW BAR 1.968"OD X .492W X 2.0LG SS304
2	1	BOTTOM PLATE DETAIL	BPD-1-4-C (ITEM 2) & WD-2-4-D
1	1	COIL DETAIL	BPD-1-4-C (ITEM 1)

	NAME	DATE
EXPERIMENTER		
CONSULTANT		
DESIGN ENGR	L.J. ADDESSI	4/27/01
APPROVED		

COLUMBIA UNIVERSITY
NEVIS LABS
eCHAMBER

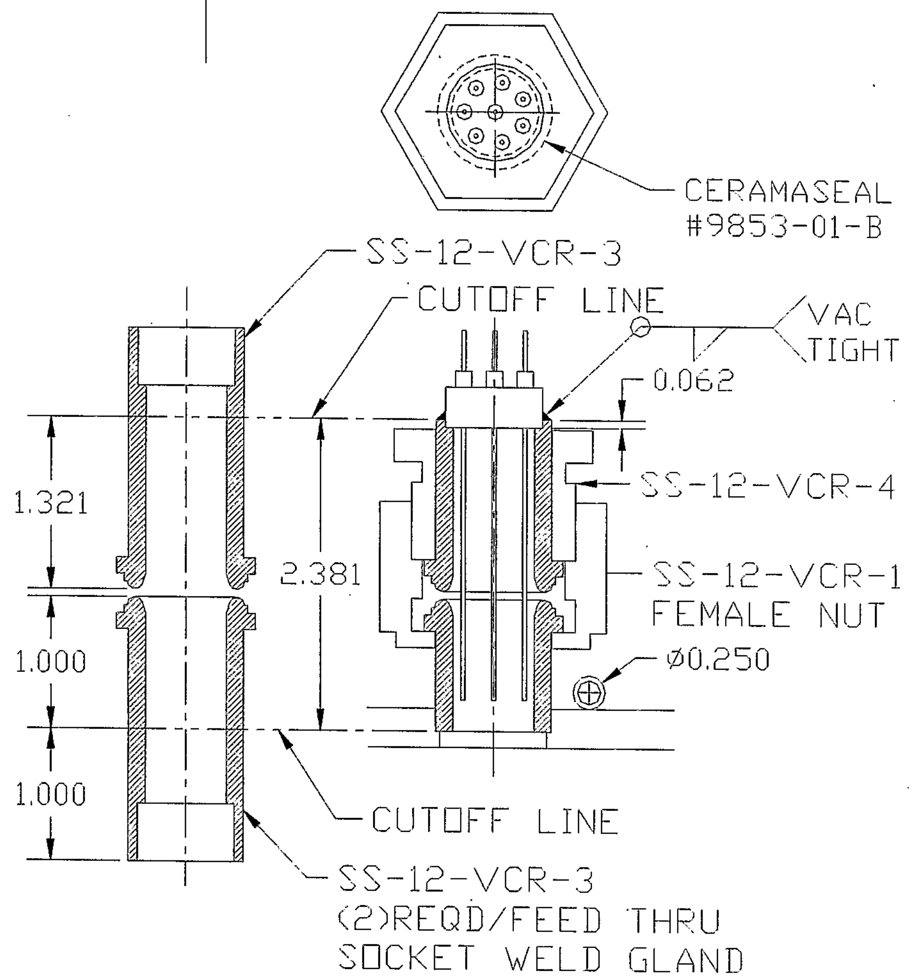
BOT PLATE ASSY | SA-3-4-F

RELEASED-8/21/01



NEXT ASSY	SA-3-4-F	SCALE	FULL	SECTION	XXX
TITLE	HV FEED THRU'S	XXX			SK-3-1-G

REVISIONS				
ZONE	REV	DESCRIPTION	DATE	APPROVED



COLUMBIA UNIVERSITY
NEVIS LABS

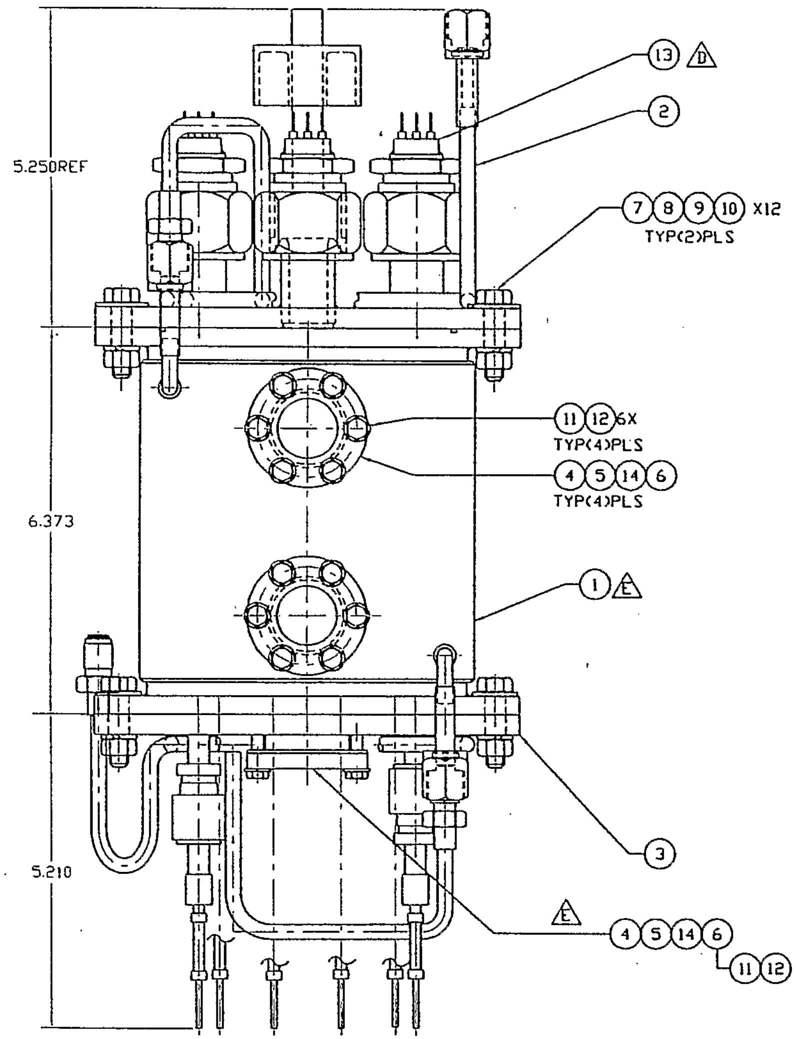
LOW VOLTAGE
FEED THROUGH

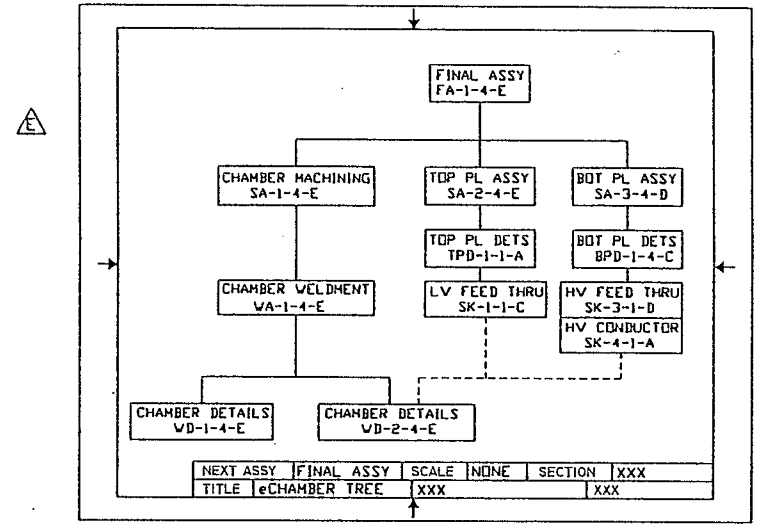
SIZE	FSCM NO.	DWG NO.	REV
A		SK-1-1-B	A

SCALE	SHEET
FULL	

FA-1-4-E

REV	DESCRIPTION	DATE	APPROVED
D	ADDED ITEM 13	4/10/01	
E	REVISED PICTURE,CHANGED BOT WINDOW	5/1/01	





ITEM	QTY	DESCRIPTION	MATERIAL/MFG
X	X	X	X
14	5	PAD	SA-3-4-D(ITEM 15)
13	4	LOW VOLTAGE FEED THROUGH ASSY	SK-1-1-C
12	30	WASHER,FLAT #10	STL OR SS
11	30	SCR,HEX HD #10-32NF X .75LG	STL OR SS
10	24	NUT,HEX 5/16-18NC	STL OR SS
9	24	WASHER,LOCK 5/16	STL OR SS
8	24	WASHER,FLAT 5/16(.75 OD)	STL OR SS
7	24	SCR,HEX HD 5/16-18NC X 1.25LG	STL OR SS
6	5	CLAMP,WINDOW	SA-3-4-D(ITEM 14)
5	5	WINDOW	OPTICAL GLASS(SUPPLIED BY NEVIS)
4	AR	WIRE,INDIUM	ø.095
3	1	BOTTOM PLATE,DETAILS & ASSEMBLY	SA-3-4-D
2	1	TOP PLATE,DETAILS & ASSEMBLY	SA-2-4-D
1	1	CHAMBER,MACHINE ASSEMBLY	SA-1-4-D

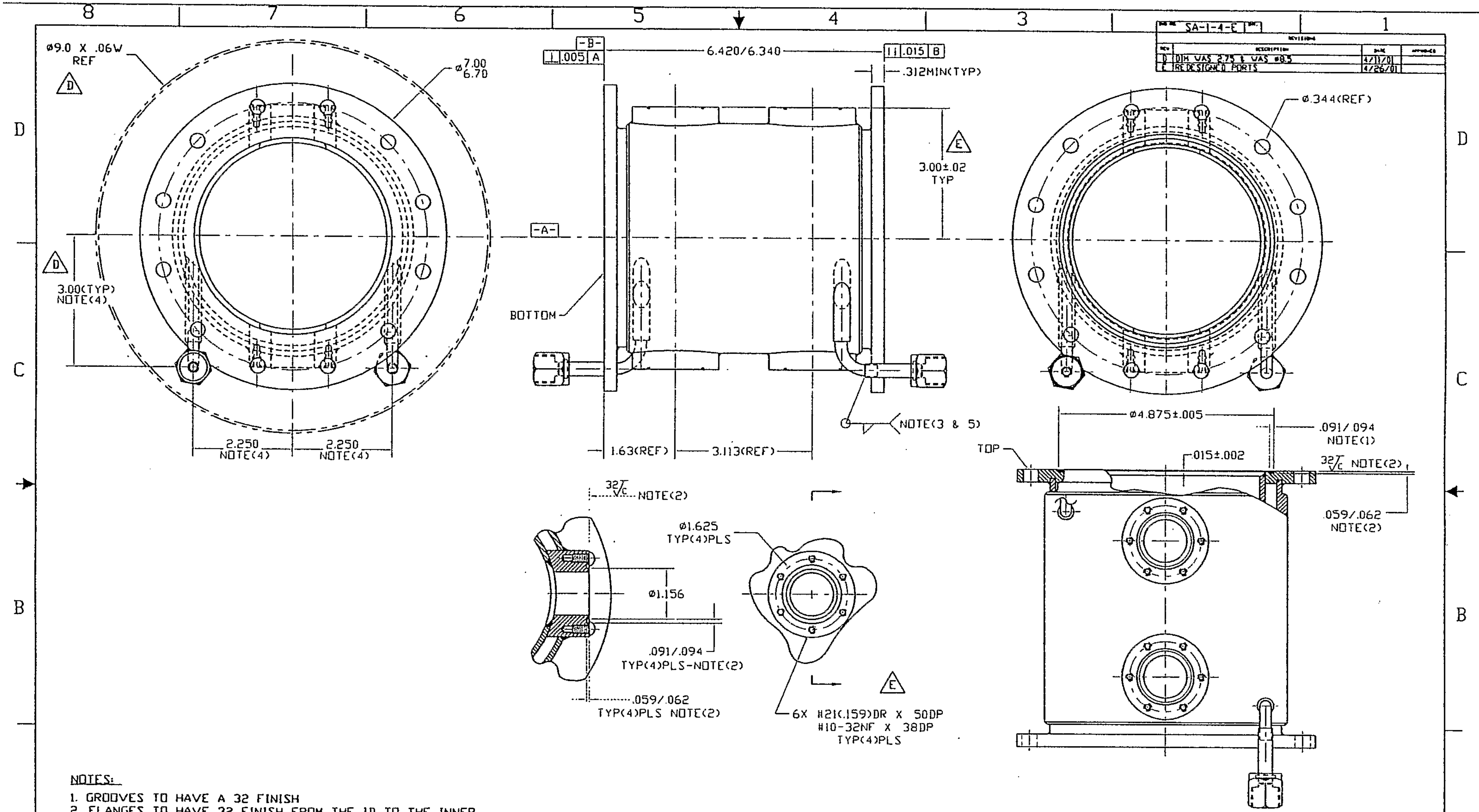
EXPERIMENTER	
CONSULTANT	
DESIGN ENGR.	L.J. ADDESSI
APPROVED	
DATE	3/2/01

COLUMBIA UNIVERSITY
NEVIS LABS

eCHAMBER

FINAL CHAMBER ASSY | FA-1-4-E

RELEASED-4/3/01

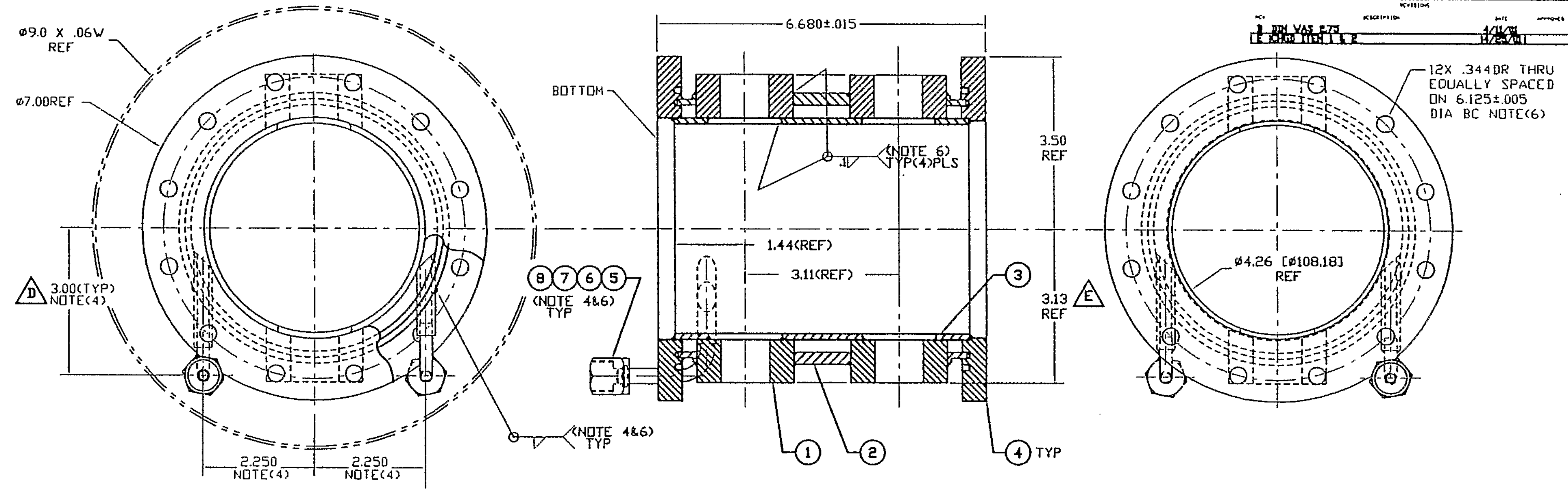


NOTES:

1. GROOVES TO HAVE A 32 FINISH
2. FLANGES TO HAVE 32 FINISH FROM THE ID TO THE INNER EDGE OF THE BOLT HOLES
3. WELD AFTER MACHINING
4. MATE WITH TOP ASSY(SA-2-4-D) & BOT ASSY(SA-3-4-D) TO POSITION FOR WELDING
5. WELDS TO BE VACUUM TIGHT

ITEM	QTY	DESCRIPTION	MATERIAL/MFG
X	X	X	X

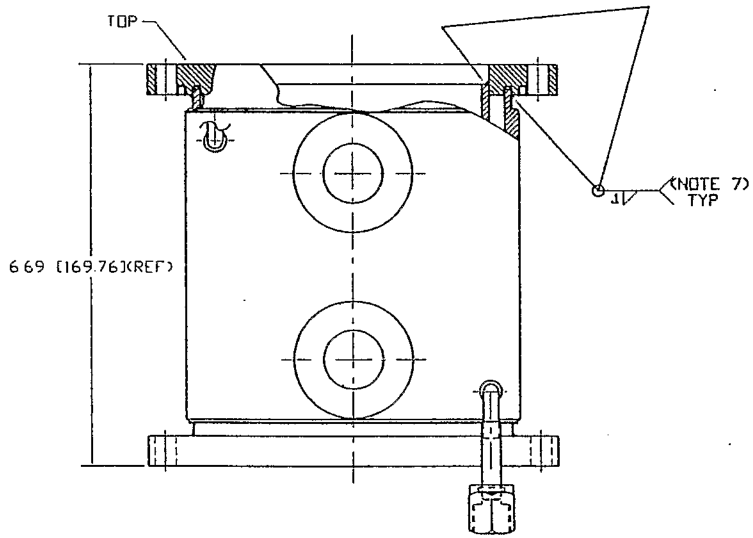
EXPERIMENTER		COLUMBIA UNIVERSITY NEVIS LABS
CONSULTANT		
DESIGN ENGR.	L.J. ADDESSI	eCHAMBER
APPROVED		
DATE	4/26/01	MACHINING ASSEMBLY SA-1-4-E



WELDING & LEAK CHECK PROCEDURE

1. TACK WELD FLANGES(ITEM 4) TO INNER & OUTER CYLINDERS
2. INSERT ITEM 1 & CHECK OVERALL DIMENSION & TACK WELD
3. TACK WELD BOTTOM FLANGE(ITEM 4) TO CYLINDERS. CHECK OVERALL LENGTH & ALIGNMENT OF FLANGES BEFORE WELDING FLANGES & CYLINDERS.
4. WELD He SUPPLY & RETURN PORTS ITEMS 1,5 & 6 - USE ITEMS 7&8 TO POSITION ITEMS 5 & 6 - ITEMS 7&8 TO BE WELDED AFTER MACHINING - SEE (SA-1-4-D)
5. LEAK CHECK INNER & OUTER CYLINDER WALL WELDS USING BLANKOFF FLANGES(ITEM 8) & He SUPPLY & RETURN PORTS
6. HOLES MAY BE SPOT DRILLED FROM BLANKOFF FLANGES SEE DWG WD-2-4-D
7. WELD TO BE VACUUM TIGHT

SEE DWG WD-1 & 2-4-D FOR DETAILS



ITEM	QTY	DESCRIPTION	MATERIAL/MFG
9	X	X	X
8	2	GLAND,SOCKET WELD	CAJON #SS-4-VCR-3
7	2	NUT,FEMALE	CAJON #SS-4-VCR-1
6	2	ELBOW,90 304SS	TRULY TUBULAR #90MM4
5	2	TUBE, .375 OD X .065W X 3" 304SS	TUBE SALES
4	2	FLANGE,SS304 PLATE .5THK X 7.0 DIA	TUBE SALES
3	1	TUBE 4.50 OD X .12W X 6.00 304SS	TUBESALES
2	1	TUBE 5.50 OD X .25W X 6.00 304SS	TUBESALES
1	4	FLANGE,HOLLOW BAR SS304	1.968 OD(50mm) X .492 W(12.5mm) X 1.5LG(38mm)

EXPERIMENTER	
CONSULTANT	
DESIGN ENGR.	L.J. ADDESSI
DATE	4/25/01
APPROVED	

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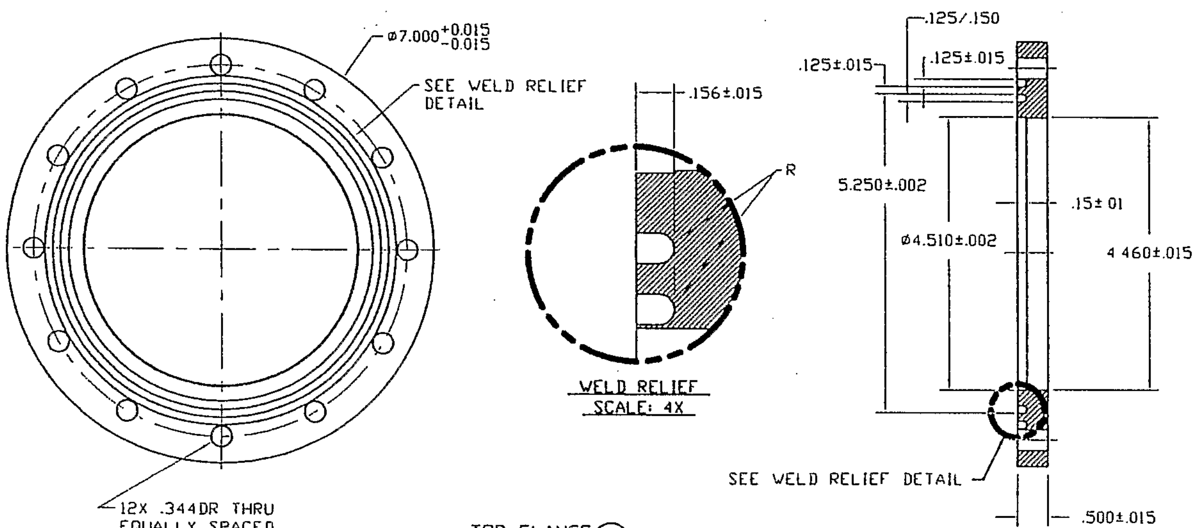
eCHAMBER
WELDMENT ASSEMBLY WA-1-4-E

WD-1-4-E

REVISIONS

E REDESIGNED ITEM(1)TEXT 4/25/01

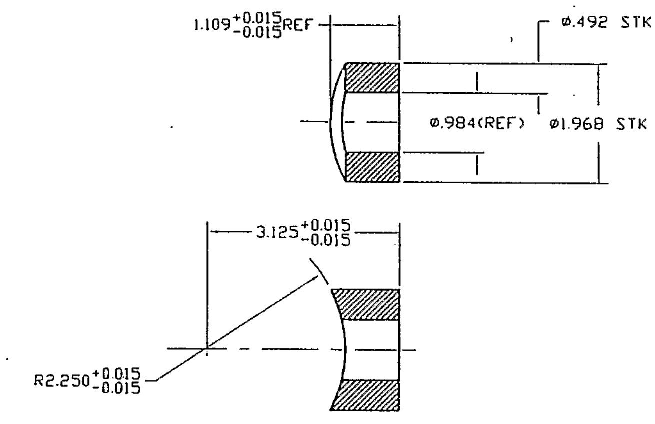


WELD RELIEF
SCALE: 4X

TOP FLANGE (5)

MATERIAL: SEE WELDMENT ASSY(WA-1-4-B)

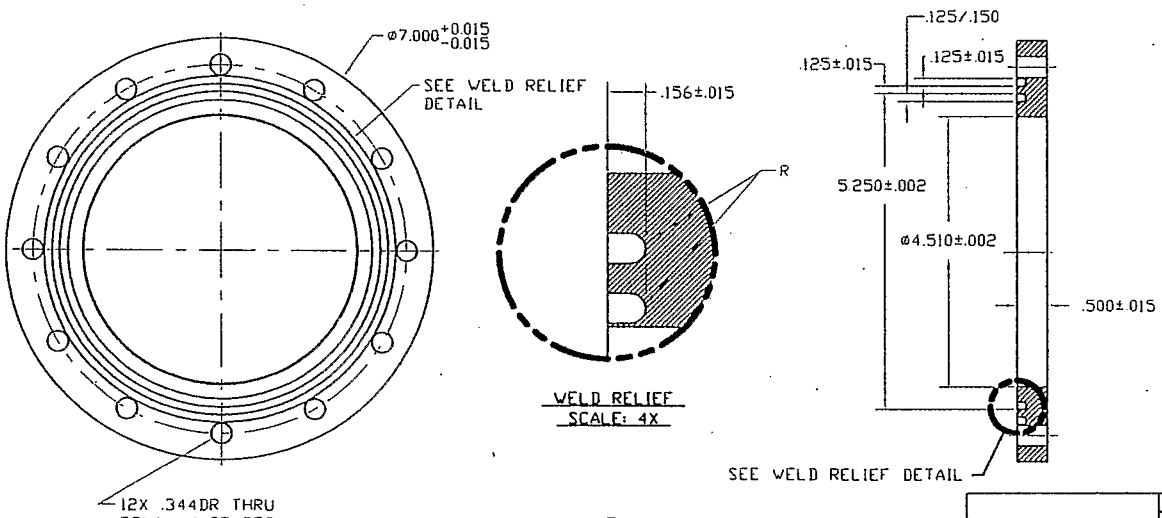
NOTE: 1) HOLES MAY BE SPOT DRILLED FROM ITEM 10/11 (WD-2-4-C)



PORT (1) E

MATERIAL: SEE WELDMENT ASSY(WA-1-4-A)

REQD: 4

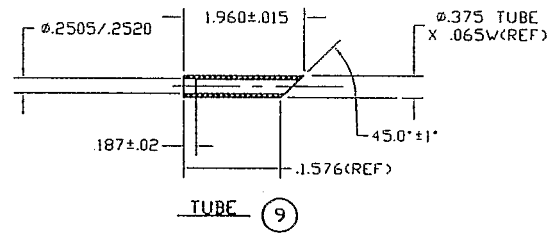


WELD RELIEF
SCALE: 4X

BOTTOM FLANGE (5)

MATERIAL: SEE WELDMENT ASSY(WA-1-4-B)

NOTE: 1) HOLES MAY BE SPOT DRILLED FROM ITEM 10/11 (WD-2-4-C)



TUBE (9)

MATERIAL: SEE WELDMENT ASSY(WA-1-4-B)

REQD: 2

	NAME	DATE
EXPERIMENTER		
CONSULTANT		
DESIGN ENGR.	L.J. ADDESSI	4/25/01
APPROVED		

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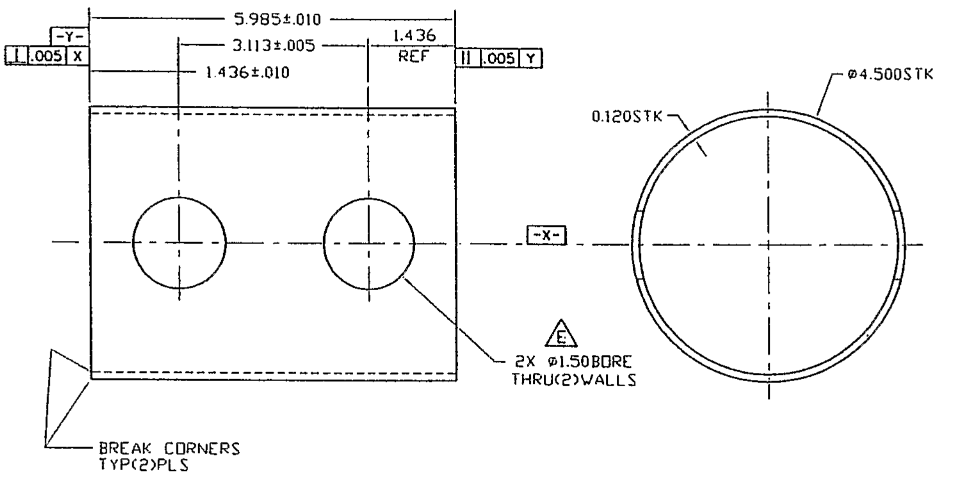
WELDMENT DETAILS | WD-1-4-E

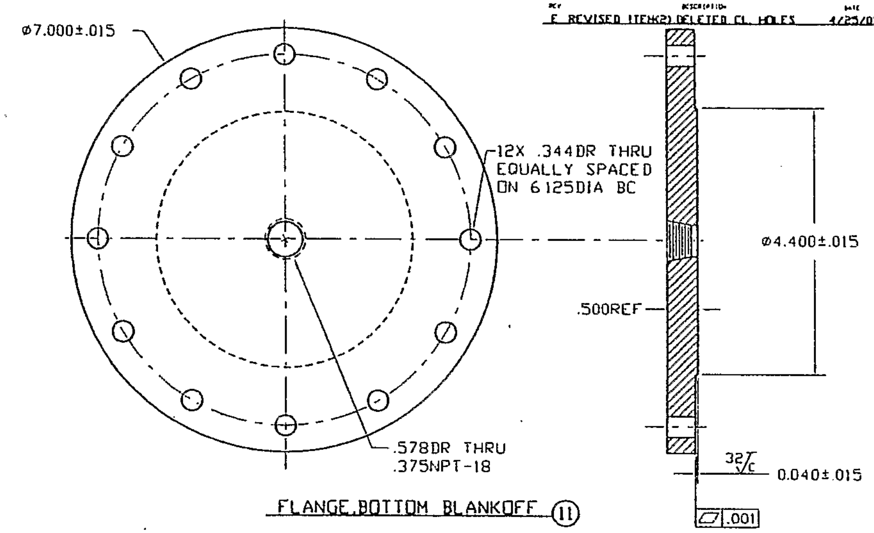
WD-2-4-E

E REVISED ITEM(2) DELETED CL HOLES 4/25/01



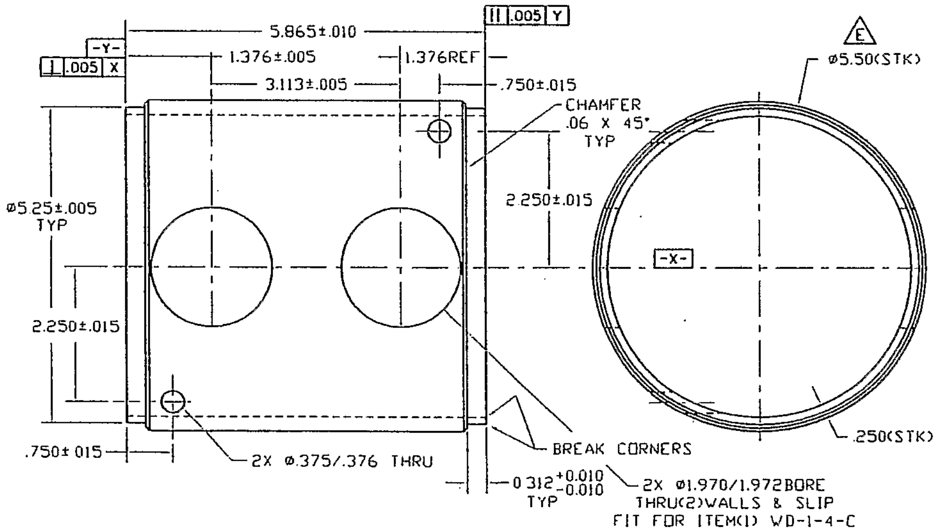
TUBE ③

MATERIAL: SEE WELDMENT ASSY(WA-1-4-C)



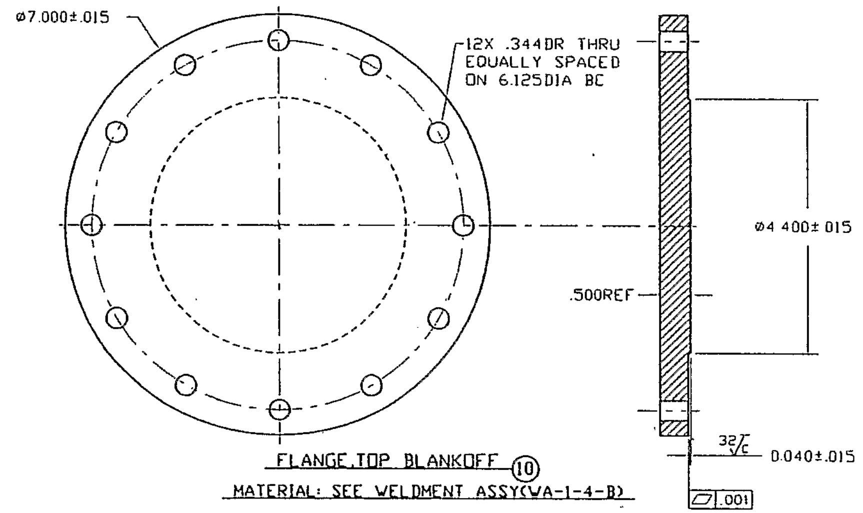
FLANGE,BOTTOM BLANKOFF ⑪

MATERIAL: SEE WELDMENT ASSY(WA-1-4-C)



TUBE ②

MATERIAL: SEE WELDMENT ASSY(WA-1-4-C)



FLANGE,TOP BLANKOFF ⑩

MATERIAL: SEE WELDMENT ASSY(WA-1-4-B)

	NAME	DATE
EXPERIMENTER		
CONSULTANT		
DESIGN ENGR.	L.J. ADDESSI	4/25/01
APPROVED		

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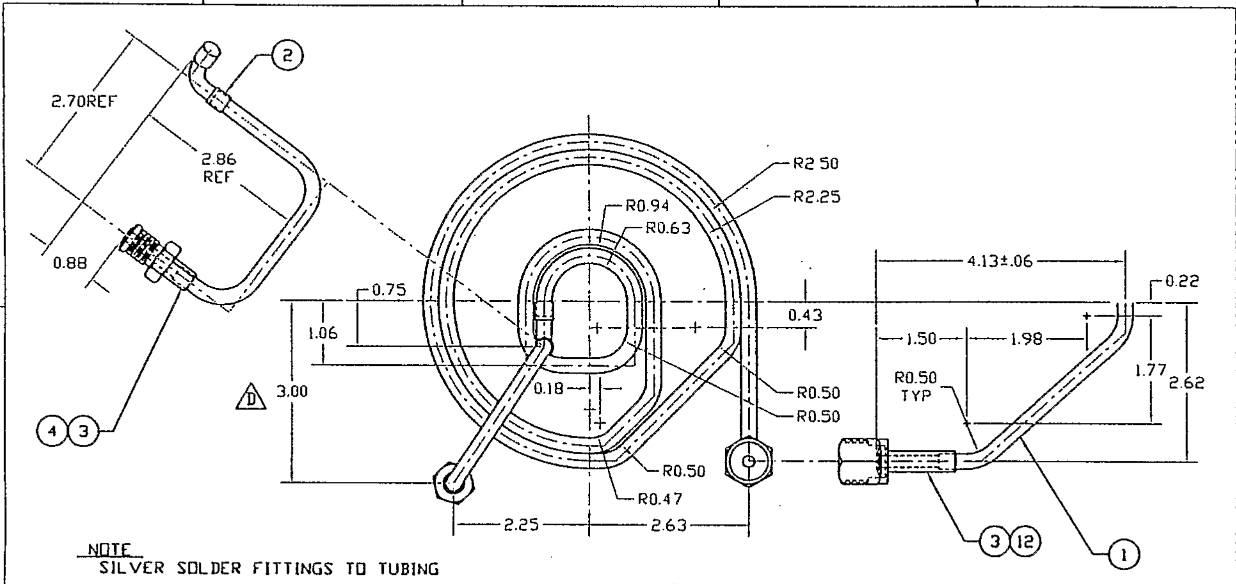
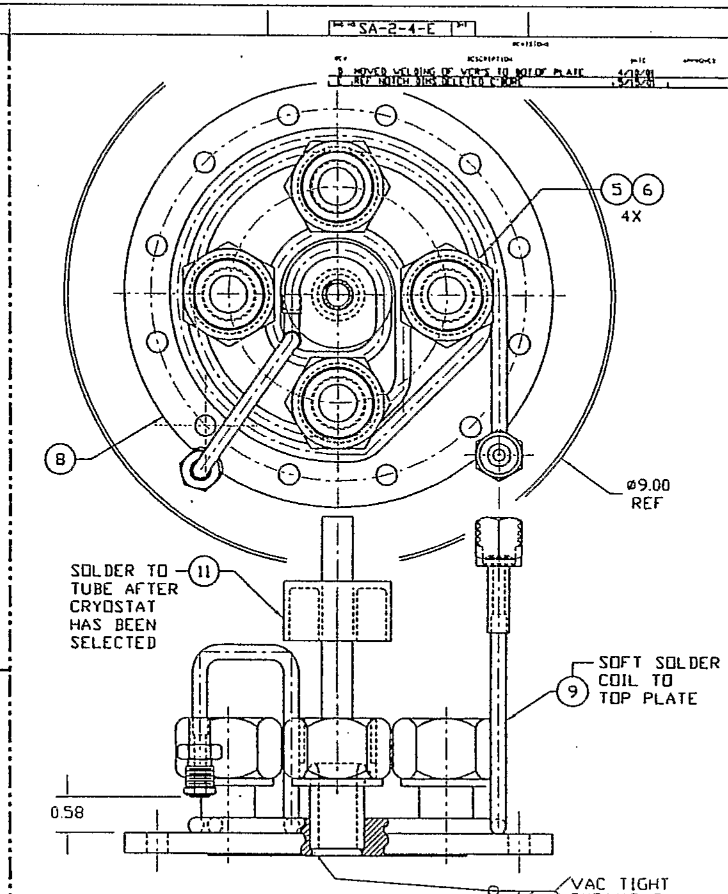
WELDMENT DETAILS | WD-2-4-E

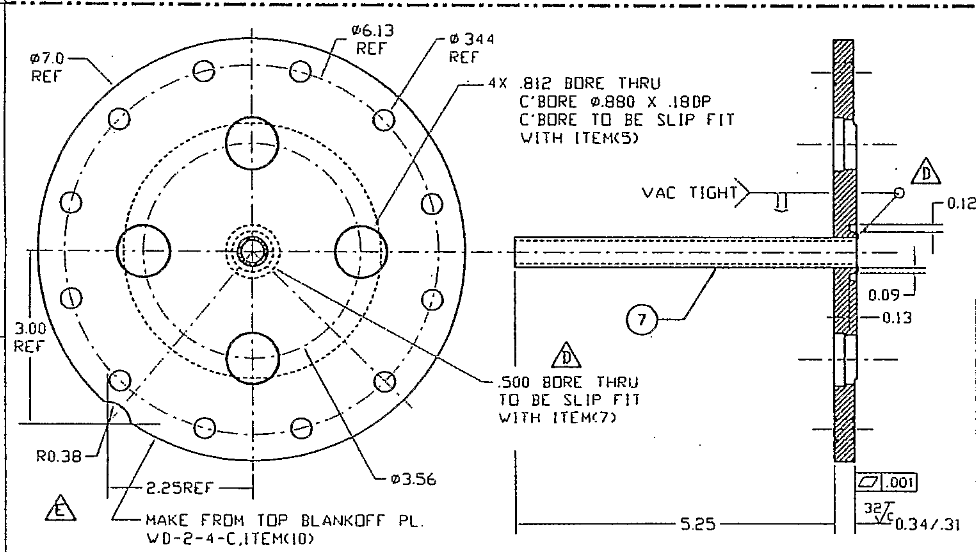
RELEASED 4-5-01



COIL DETAIL 9



TOP PLATE ASSEMBLY



TOP PLATE DETAIL 8

ITEM	QTY	DESCRIPTION	MATERIAL/MFG
11	1	COLD SINK DETAIL	TPD-1-1-A
10	1	GLAND,SOCKET WELD	CAJON #SS-8-VCR-3
9	1	COIL DETAIL	THIS DWG
8	1	TOP PLATE DETAIL	THIS DWG & SEE WD-2-4-D (ITEM 10)
7	1	TUBE, .50 OD X .065W X 6.0LG	TUBE SALES
6	4	NUT,FEMALE	CAJON #SS-12-VCR-1
5	4	GLAND,MODIFIED (CAJON SS-12-VCR-3)	DWG #SK1-LV FEED THRU
4	1	NUT,MALE	CAJON #SS-4-VCR-4
3	2	GLAND,SOCKET WELD	CAJON #SS-4-VCR-3(SEE SK-1-1-C)
2	1	ELBOW,90FF 304SS	TRULY TUBULAR #90FF4
1	AR	TUBING,1/4 OD X .03W COPPER	REFRIGERATION TUBING(SOFT)

	NAME	DATE
EXPERIMENTER		
CONSULTANT		
DESIGN ENGR.	L.J. ADDESSI	4/27/01
APPROVED		

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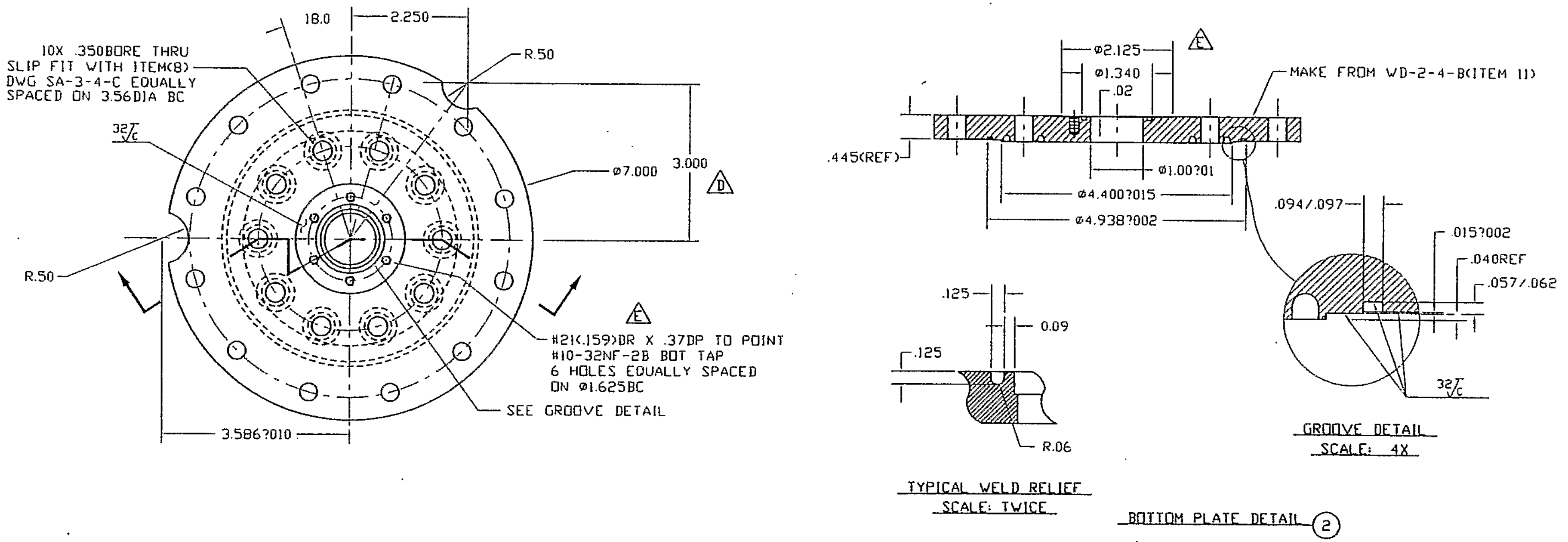
NEVIS LABS
eCHAMBER
TOP PL. DET. & ASSY | SA-2-4-E
RELEASED-4/3/01

BPD-1-4-E

REV	DESCRIPTION	DATE	APPROVED
D	DIM WAS 2.75	4/11/01	
E	ADDED GROOVE & MTG HOLES/WINDOW	4/28/01	



NOTE BREAK ALL SHARP CORNERS & INSIDE RADII TO BE .02R UNLESS OTHERWISE NOTED

	NAME	DATE
EXPERIMENTER		
CONSULTANT		
DESIGN ENGR.	L.J. ADDESSI	4/28/01
APPROVED	L.X. JIA	6/13/01

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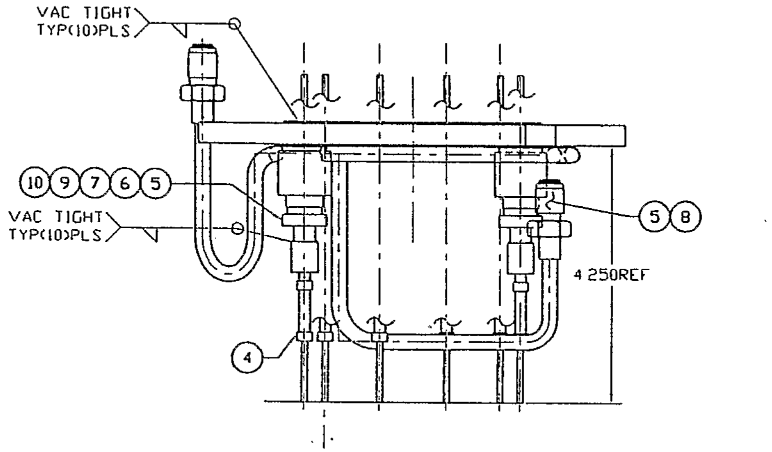
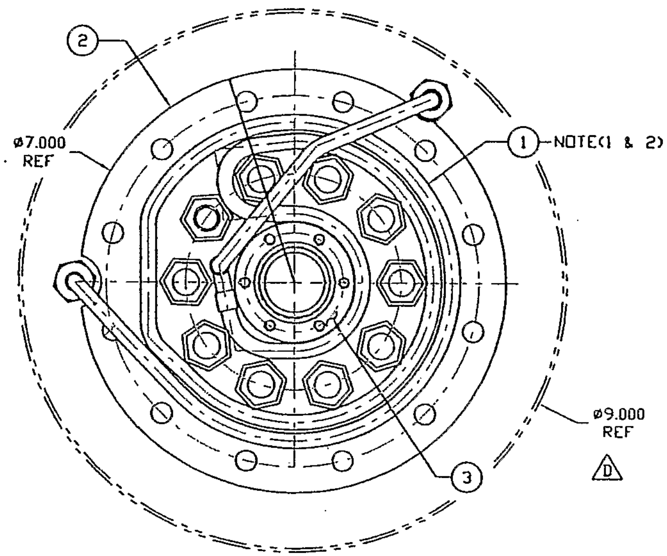
eCHAMBER
BOT PLATE DETAIL | BPD-1-4-E
RELEASED-4/3/01

SA-3-4-F

REV	DESCRIPTION	DATE
D	REVISED PIC FOR DETS ADDED ITEM 15	4/27/01
F	REVISED FOR HV FEED THRU	8/21/01

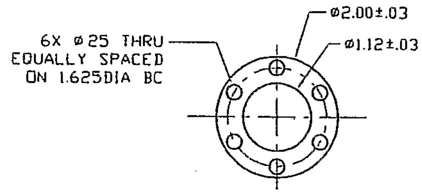




BOTTOM PLATE ASSY

NOTE:

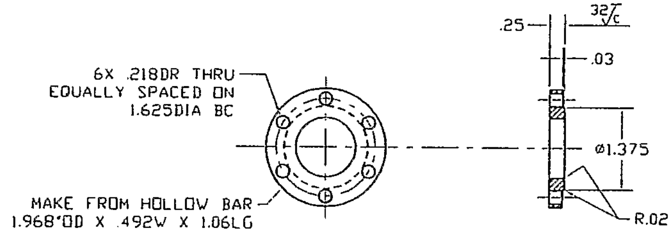
1. LEAK CHECK VCR WELDS & PORT BEFORE SOLERING COIL TO TOP PLATE
2. LEAK CHECK COIL ASSY BEFORE SOLDERING TO TOP PLATE



PAD 15

MAT: .06THK TEFLON

NOTE: USED ON MAIN ASSEMBLY FA-1-4-D



WINDOW CLAMP 14
REQD: 5

NOTE:

1. BREAK ALL SHARP EDGES
2. USED ON MAIN ASSEMBLY FA-1-4-D

ITEM	QTY	DESCRIPTION	MATERIAL/MFG
15	5	PAD(THIS DWG)	TEFLON .06THK
14	5	WINDOW CLAMP DETAIL(THIS DWG)	HOLLOW BAR 1.968"OD X .492W X 3.0LG SS304
13	AR	TUBING,1/4 OD X .03W COPPER	REFRIGERATION TUBING(SOFT)
12	1	ELBOW,90FF4 304SS	TRULY TUBULAR #90FF4
11	X	X	X
10	10	GLAND,SHORT SOCKET WELD	CAJON # SS-4-VCR-3-75LG (SEE SK-3-1-G)
9	-	X	X
8	12	GLAND, SOCKET WELD	CAJON #SS-4-VCR-3(SEE SK-3-1-G & BPD-1-4-E
7	10	GASKET,COPPER	D19-M-6178-1
6	10	NUT,FEMALE	CAJON #SS-4-VCR-1
5	12	NUT,MALE	CAJON #SS-4-VCR-4
4	10	FEED THRU ,SINGLE CONDUCTOR	CERAMASEAL #4275-22-W (SEE SK-3-1-G)
3	1	PORT DETAIL (THIS DWG)	HOLLOW BAR 1.968"OD X .492W X 2.0LG SS304
2	1	BOTTOM PLATE DETAIL	BPD-1-4-C (ITEM 2) & WD-2-4-D
1	1	COIL DETAIL	BPD-1-4-C (ITEM 1)

	NAME	DATE
EXPERIMENTER		
CONSULTANT		
DESIGN ENGR.	L.J. ADDESSI	4/27/01
APPROVED		

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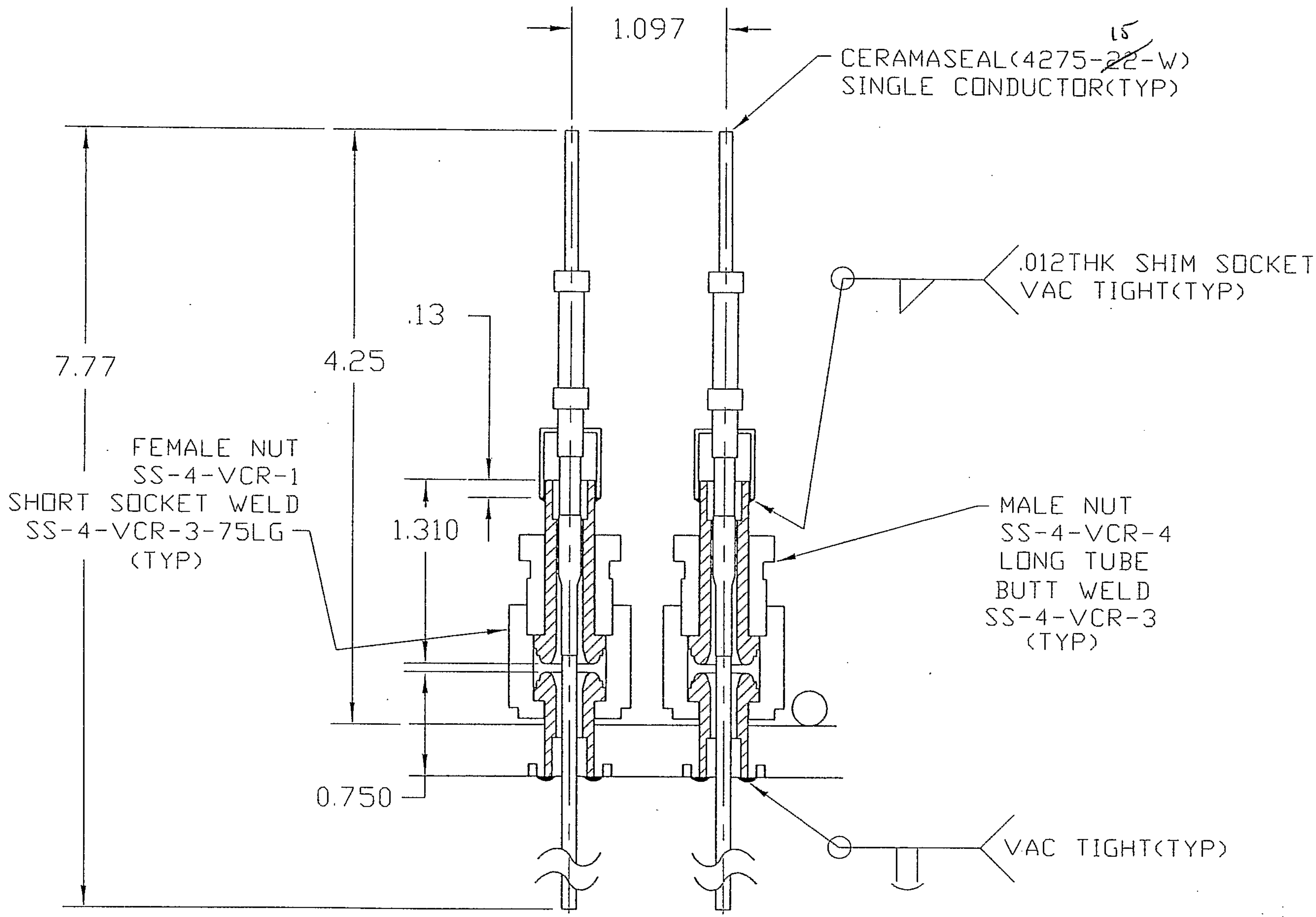
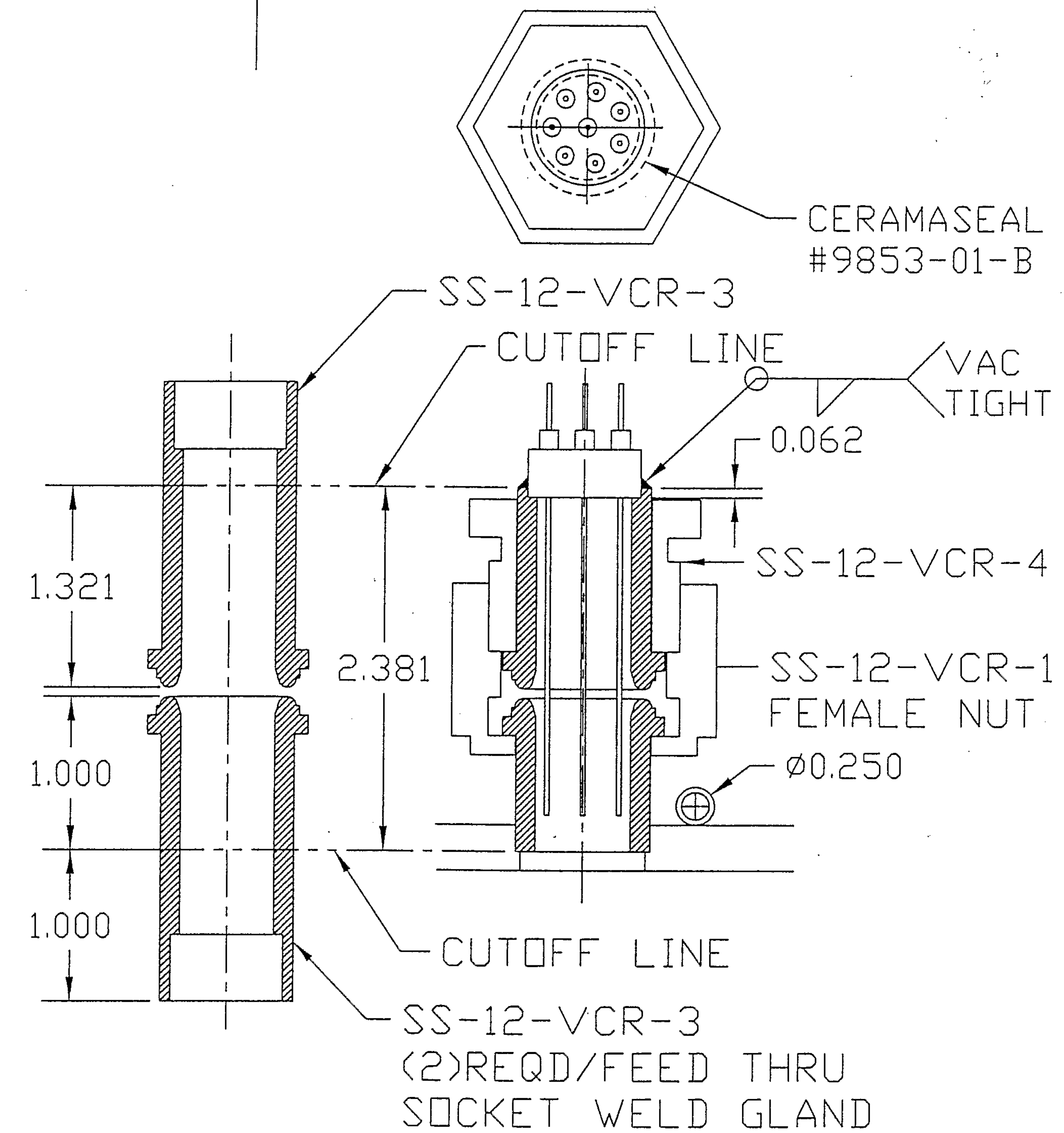
eCHAMBER
BOT PLATE ASSY SA-3-4-F
RELEASED-8/21/01



NEXT ASSY	SA-3-4-F	SCALE	FULL	SECTION	XXX
TITLE	HV FEED THRU'S	XXX			SK-3-I-G

REVISIONS

ZONE	REV	DESCRIPTION	DATE	APPROVED



COLUMBIA UNIVERSITY
NEVIS LABS

LOW VOLTAGE
FEED THROUGH

SIZE	FSCM NO.	DWG NO.	REV
A		SK-1-1-B	A

SCALE	SHEET
FULL	

9. Determine whether the Janis cryostat is built to code

The cryostat vacuum vessel is designed to ASME code, but is not stamped (see Attachment 1, bullet 1). The central fill tube is designed to withstand a pressure of 150 psi, and is also designed to ASME code (see Attachment 1, bullet 3 and Attachment 2, bullet 3).

Attachments:
1. Cryostat specification provided by vendor (Janis).
2. Copy of 10 May, 2003 e-mail from vendor (Janis).

JANIS

Model 16CNDT Optical Liquid Helium Cryostat for use in an Electron Bubble Chamber

The system consists of the following components:

1. A model 16CNDT nonmagnetic stainless steel, superinsulated nitrogen shielded liquid helium research dewar with multi-layer superinsulation. The dewar has a nominal useful helium capacity of 35 liters , with a static hold time of greater than 6 days (depending on the added wiring heat load). The nitrogen reservoir will have a capacity of ~35 liters and a hold time of > 4 days, with no added heat load. The vacuum shell will be designed to ASME code.

2. The vacuum jacket will have a bellows sealed evacuation valve and will be protected through a pressure relief valve to ensure .that the pressure will not exceed 5 psig due to any accidental cold leaks from either reservoir. In addition, each reservoir will have similar pressure relief valves to vent the evaporating cryogens.

3. The helium reservoir will include a liquid helium valve and operator .to supply helium to a customer built cell. The feed line will have an OD of 0.093" OD and will end in a standard VCR fitting. In addition, there will be a central insert designed to withstand a pressure of 150 psi, ending in a 0.75" OD tube and standard VCR fitting below the helium reservoir. A similar VCR fitting is welded to the top of the 0.75" OD tube at the top of the cryostat, and is supplied with a pressure relief valve that is set to vent any pressures above 150 psig.

4. The cryostat also includes a 0.5" OD vent line, which narrows down to .0.375" below the nitrogen reservoir, and ends in a standard VCR fitting below the helium reservoir. This is designed to mate with a customer supplied cell and will allow either pumping or simple venting of the helium in the customer provided cell.

5. The top flange of the cryostat will include five NW-40 flanges for customer supplied electrical feedthroughs. It will also include an additional 19-pin feedthrough to the vacuum space and an 8-pin feedthrough to the helium reservoir. None of these feedthroughs will be wired by Janis Research. Thermal anchoring spots will be offered to thermally anchor any customer wiring to the nitrogen and helium reservoirs.

6. A bottom removable tail section that includes room temperature , liquid nitrogen temperature and liquid helium temperature tails, each having four windows that are aligned to offer optical access to the customer supplied cell inside the He-4 radiation shield. All window supplied will be Infrasil fused quartz windows, and all windows will be easily replaceable for using other window materials. The bottom of this tail region will also include a window in each layer (outer jacket, nitrogen and helium radiation shield) to provide optical access to the cell.

7. The tail region will also include a total of three 19 pin electrical feedthroughs and four 8 pin electrical feedthroughs for customer use. All feedthroughs are removable and none will be wired by Janis Research.

8. Complete liquid helium testing of the cryostat at our facility to ensure that the systems operates with no warm or cold leaks that would affect the operation of the cryostat. All VCR fittings will be sealed with mating fittings during the final test. Since the customer supplied inner cell is not supplied by Janis Research, we cannot guarantee cannot guarantee the leak tightness or proper operation of this cell after it is inserted into our cryostat.

Date: Sat, 10 May 2003 09:33:58 -0400
From: Munir Jirmanus <mjirmanus@janis.com>
To: 'Jeremy Dodd' <dodd@nevis.columbia.edu>
Subject: RE: Columbia/BNL 16CNDT cryostat

Dear Jeremy,

I will attempt to answer all your questions in the same order they appeared.

1. What venting scenarios were considered in determining the size (1/2") of the pressure relief valves on the cryostat?

The pressure relief valves are selected based on our practical knowledge developed over the years since our company was established (1961).

2. The LN2 reservoir has three open holes at the top, for filling and venting - is there a risk of back-flow of water vapor into the holes with associated ice build-up, and if so, what modifications can be made to prevent this?

The risk is minimal. You can prevent it by adding either "Bunsen" type valves (rubber tubes with a slit for venting and sealed with a stopper), simple rubber tubes long enough to make a U turn and end up pointing downwards, or more costly pressure relief valves (or one valve with the three exits joined together) added to the entrances. Typically this can be done using an O-ring compression seal against the outgoing tubes, soldered to a cap with the pressure relief valves threaded in position.

3. The vacuum vessel is designed to ASME code (though not stamped) - are the reservoirs also to code?

The reservoirs are not designed to ASME code because this would contradict the cryogenic requirements of this unit (thin-wall tubes to reduce the heat load into the two reservoirs). These reservoirs are not vacuum vessels, and they operate at atmospheric pressure or slightly (~2 psi) over. The innermost tube (0.75" OD x 0.0625" wall) is designed to operate at high pressure and is thus designed to code.

Best regards,

Munir

****
PS. Please acknowledge receipt of this email message to ensure the continuity of communications.
****

Munir N. Jirmanus, Ph.D.
Vice President - Technical Sales & Development
Janis Research Company, Inc.
2 Jewel Drive - P.O. Box 696
Wilmington, MA 01887 USA

Telephone : (978) 657-8750, X-110
Fax : (978) 658-0349
Email : janis@janis.com or mjirmanus@janis.com
http://www.janis.com

-----Original Message-----

Before using a copy of this form, verify that it is the most current version by checking with your Experiment Review Coordinator. **Double-click to change the state of a checkbox.**

EXPERIMENT SAFETY REVIEW FORM

REVIEW NUMBER (supplied by ERC): PO2003-083

PRINCIPAL INVESTIGATOR: Jeremy Dodd, P. Rehak (BNL) **DATE: 04/04/03**

GROUP: Columbia University Nevis Labs

EXT: (914) 591 2821 **E-MAIL: dodd@nevis.columbia.edu** **LIFE NUMBER: D6288**

Project Title: Electron Bubble Chamber Project
Location(s): Building 832
Funding Source/Account Number:
Proposed Start Date and Duration: 04/01/03 for 24 months

SIGNATURES:

Principal Investigator:	**Date:**
Experiment Review Coordinator:	**Date:**
ESRC Chairman:	**Date:**
	Date:
	Date:
	Date:
	Date:
Approval Department Chairperson:	**Date:**
Review/Approval Comments: This experiment was reviewed and approved by the Department ES&H Committee, contingent on approval of the Cryogenic Safety Committee, and other Engineering reviews.	
Walkthrough Signature:	**Date:**
Expiration Date (max 1 yr.): June 15, 2004	
FUA Change Required? ☐ Y ☑ N	**Fire Rescue Run Card Changes Required?** ☐ Y ☑ N
Has a NEPA Review been Performed for this Project? ☐ Y ☑ N	
Project Termination Acceptance Signature:	**Date:**
Comments:	

I. DEFINE THE SCOPE OF WORK

A. Description

Describe the experiment purpose/scope. Identify all apparatus that will be used, and associated requirements. List special equipment (X-ray generators, lasers etc.) that will be used during the project. Identify measurement and test equipment, apparatus operating conditions, and required maintenance procedures as appropriate. Include calibration frequency for formal calibration requirements. Attach supporting documents such as engineering calculations, drawings and specifications.

Indicate if modification of facility is required. Include the setup and decommissioning phases of the experiment. The Work Permit Process/Form may better address the hazards & controls of the set-up and/or tear down phases. Indicate if a Work Permit will be used.

(1) Setup the test station.
(2) Hydraulic pressure test (Room temperature). Test pressure: 200psig (with quartz windows and HV feed-throughs).
(3) Leak check of the Test Chamber at LN2 temperature. Check points: LHe vessel, Windows ports, HV feedthrough, LV feedthrough, Cooling loops. There are 4 low voltage feed-through ports (4x8 pins) on the side of the vacuum chamber.
(4) Test boiling-off rate of LHe of the LHe/LN2 Cryostat.
(5) Weld, mount and check the temperature sensors (12) and the electrical heater (1) (1 week).
(6) Install the HV cables and LV cables into the LHe/LN2 Cryostat (3 days). There are 20 high voltage cables (10 kV for each with negligible current) from the bottom flange of the Test Chamber, which need thermal interception at 4.2K and 77K levels. Only ten cables will be used for the current Test Chamber. Each conductor wire is electrically insulated by a Teflon coating sleeve of 3 mm outside diameter. The high voltage cable will be provided to the vender for pre-installation along the outer surfaces of the LHe vessel and LN2 vessel.
(7) Install the Test Chamber into the LHe/LN2 Cryostat (1 day).
(8) Test boiling-off rate of LHe of the Cryostat with Test Chamber and HV and LV cables (1 week).
(9) Test operating parameters: Temperatures, pressure, flow rate, feedthrough grounding, boiling-off rate (2 weeks).
(10) Operate Cryostat and Test Chamber with LHe (ongoing).

See http://www.nevis.columbia.edu/~eBubble/review/revdocs.html for a complete description of the experiment, and all apparatus to be used.

B. Materials Used /Waste Generated

List materials to be used and wastes generated. Refer to the BNL Chemical Management System for a complete listing of the chemicals in your locations. Include samples, chemicals, controlled substances, gases, cryogens, radioactive materials, and biological material. You may use generic chemical class descriptions for commonly used materials (e.g., organic solvents, acids). List disposal methods. ***Denote disposal method using the codes below.***

Materials Used & Wastes Generated	Disposal Method Type (Code below)	Estimated Quantity (provide units)		Estimated Annual Waste Generation
		Per Use	Total/Yr	
Liquid Helium	F	75 l	1500 l	
Liquid Nitrogen	F	50 l	1000 l	
Gaseous Helium	F	200 l	4000 l	
Indium wire	I		100 g	
Epoxy	I/T		10 g	

Note: Identify Age Sensitive materials or special handling requirements.

Disposal Method Codes:

Air Emissions	Liquid Effluents	Wastes
P = Point Source	**S** = Sanitary	**H** = Hazardous

F = Fugitive	**ST** = Storm water	**I** = Industrial (Non-hazardous waste e.g., oils)
	O = Other	**R** = Radioactive
		M = Mixed (Radioactive + Hazardous)
		RM = Radioactive Medical
		MW = Medical
		T = Trash

C. Waste Minimization/Pollution Prevention

Describe how you plan to minimize generation of the wastes described above, and identify pollution prevention opportunities. Consider Ordering/using the smallest amount, using recycled material substituting non-hazardous materials. The *<u>Pollution Prevention and Waste Minimization Subject Area</u>* *describes how to plan, conduct, and closeout work activities to eliminate or minimize the impact of their activities on the environment.*

Usage of liquid helium and liquid nitrogen will be minimized by careful monitoring of the cryostat during and after cryogen-filling operations. Indium wire is reused when practical.

II. IDENTIFY AND ANALYZE HAZARDS ASSOCIATED WITH THE WORK

In this section indicate the hazards in each class. Include the setup and decommissioning phases of the experiment.

Physical Hazards (check all that apply)	☐ None	
☑ Cryogens	☐ Oxygen deficient atmosphere	☐ Noise > 85 dBA
☐ Fall hazards (e.g., ladders, elevated platforms, towers)		
☑ Material handling equipment (e.g., cranes, hoists, forklifts)		
☐ Machine shop or nonportable powered tools use		
☑ Electrical hazards (exposed conductors, large batteries, capacitors, etc)		
☐ Confined space	☐ Trenching/soil excavation	
☑ Extreme temperatures	☐ Remote location	
☐ Other (specify):		
Pressure or Vacuum Systems (check all that apply)	☐ None	
☑ Compressed gases (lecture bottles, cylinders, gas lines)		
☑ Pressurized vessels or systems		
☐ Vacuum chambers or systems with >1000 J stored energy		
☐ Autoclaves		
☐ Other (specify):		
Fire Hazards (check all that apply)	☑ None	
☐ Open flames	☐ Welding, Brazing, Silver Soldering	
☐ Flammable gases/liquids/solids	☐ Other spark producing activity	
☐ Other (specify):		

Chemical Hazards (check all that apply)		☑ None	
☐ Carcinogens	☐ Highly acute toxins	☐ Reproductive toxins	☐ Corrosives
☐ Flammable liquids	☐ Flammable solids	☐ Strong oxidizers	☐ Oils
☐ Explosives	☐ Peroxidizables	☐ Pyrophoric materials	☐ PCBs
☐ Asbestos	☐ Pesticides/herbicides	☐ Controlled substances	
☐ Highly reactive materials		☐ Perchlorates	
☐ Storage or use of Beryllium or Beryllium articles. Attach Beryllium Use Review Form if checked.			
☐ Toxic metals (e.g., As, Ba, Be, Cd, Cr, Hg, Pb, Se, Ag)			
☐ Other (specify):			

Ionizing Radiation (check all that apply)	☑ None
☐ Sealed radioactive sources	☐ Windowless radioactive sources
☐ Dispersible radioactive materials	☐ Neutron-emitting radioactive sources
☐ Non-fissionable radioactive materials	☐ Fissionable radionuclides
☐ Ionizing radiation-generating devices (x-ray sources, accelerators)	
☐ Other (specify):	

Nonionizing Radiation (check all that apply)	☐ None
☐ Class II, IIIa, or IIIb (visible <15mW) lasers	☐ Class IIIb (nonvisible >15mW) or IV lasers
☐ Dynamic magnetic fields >1G at 60 Hz or dynamic electric fields > 1kV/m at 60 Hz	
☐ Static magnetic fields < 5 G. No Exposure Form is required	
☐ Static magnetic fields > 5 G and < 600 G	☐ Static magnetic fields exposure. Attach Static Magnetic Fields Exposure Form when required.
☐ Static magnetic fields ≥600 G	
☐ Radio frequency (RF) or Microwave sources exceeding 10 mW radiated output	
☐ Infrared sources > 10 W	☑ Ultraviolet sources > 1 W
☐ Extremely low frequency (ELF) radio sources	
☐ Other (specify):	

Biological Hazards (check all that apply)	☑ None	
☐ Regulated etiological agent	☐ Recombinant DNA	☐ Animals
☐ Human blood/components, human tissue/body fluids		☐ Human subjects
☐ Other (specify):		

Offsite Work (check appropriate box)	☑ None

☐ Reviewed or controlled by ES&H programs at the offsite location	☐ Requires additional controls (include in the next section)

See Identification of Significant Environmental Aspects and Impacts Subject Area or your ECR if you need assistance completing the following table.

Significant Environmental Aspects (check all that apply) ☐ None
☐ Any amount of hazardous waste generation
☐ Any amount of radioactive waste generation
☐ Any amount of mixed waste generation (radioactive hazardous waste)
☐ Any amount of transuranic waste generation
☑ Any amount of industrial waste generation (e.g., oils, vacuum pump oil)
☐ Any amount of Regulated Medical Waste (including sharps, hypodermic needles or syringes)
☐ Any atmospheric discharges that require engineering controls to reduce hazardous air pollutants or radioactive emissions, or are identified as a Title V emission unit, or require monitoring under NESHAP
☐ Any liquid discharges that require engineering controls to limit the quantity or concentration of the pollutant, or include radionuclides detectable at the point of discharge from the facility, or contain any of the chemicals listed on BNL's SPDES permit
☐ Storage or use of any chemicals or radioactive materials that require engineering controls – see Storage and Transfer of Hazardous and Nonhazardous Materials Subject Area
☐ On-site or off-site transportation of chemicals or dispersible radioactive materials
☐ Any use of once-through cooling water with a flow of 4 gpm – 24 hrs/day (10 gpm – 8 hrs/day, daily use of >15 gpm for >60 days) and discharging to the sanitary sewer
☐ Soil contamination or activation
☐ Any underground pipes/ductwork that contains chemical or radioactive material/contamination
☐ Other environmental aspects related to your work (specify):
☐ Process Assessment Form required (determined by ECR or other qualified person)

III. DEVELOP AND IMPLEMENT HAZARD CONTROLS

*For each hazard identified in the previous section, describe how that hazard is controlled. Identify the **Engineering Controls (e.g., interlocks, shielding), Administrative Controls (e.g., procedures, RWPs) or Personal Protective Equipment (e.g., respirators, gloves; see the Personal Protective Equipment Subject Area)** that will be employed to reduce hazards to acceptable levels.*

*The Experiment Review Coordinator, along with the **Principal Investigator** (PI) and Building Manager, as appropriate, will evaluate this experiment for impacts that will require an update to the Facility Use Agreement (FUA), and or Fire/Rescue Run Cards.*

*The **PI** develops and implements hazard controls in consultation with, and using feedback from, the personnel who will be performing the work.*

General safety rules for this experiment:

- Never work alone.
- Training. Everyone touching the equipment must have passed the training for the equipment. The Operating Manual must be studied by each potential operator. A test on it must be passed before an

operator is qualified. Operators must be qualified for the current version. If there are substantial changes, a new version will be released, and all operators must re-qualify.

- Consensus. If there is a disagreement within the operating team on safety, the work must stop, and a group of responsible Columbia/BNL physicists should consider the concern before continuing.
- Log Book. There will be a Log Book for operating the e-Bubble Test Chamber System. An operating session must start with the Chief Operator signing in, writing the name of the necessary second operator, and recording the date. All significant operating steps should be entered in the Log Book.
- All significant conditions in the system and changes must be noted in the Log Book.
- Do not tamper with any pressure relief.
- Exercise caution when handling nitrogen and liquid helium. Wear a full-face shield, insulating gloves and avoid splashing liquid on clothing.
- Do not exert any lateral forces on the Dewar tails as misalignment of the tails and possible thermal shorts may result.

A. Physical Hazards/Controls

Hazard	Controls (Administrative, Engineered, Protective Equipment)
Cryogens	Cryostat and dewars are from commercial vendors (Janis, Chart respectively), and have requisite relief valves etc. Associated pumping and fill lines have been designed by L. Jia (BNL/CAD). The system is currently under review by BNL CSC. A full-face shield and insulating gloves must be worn when transferring liquid cryogens.
ODH	BNL Class 0, under a variety of normal operating conditions, and under "worst-case" cryostat failure scenarios.
Material handling equipment	Cryostat is supported on a steel-frame stand, with motor-driven variable-height support yoke. Motor has automatic cut-off if yoke is driven beyond pre-defined limits.
Electrical hazards	High voltage is low current (<10 mA) and does not represent a major hazard. All cables are industry standard rated for at least the voltages used.
Pressure vessels	Stress analysis shows vessel is within safe limits. Results from code are being reviewed by S. Kane from the BNL CSC.

<u>Note:</u> *Include maintenance, inspection and testing, and formal calibration, including frequency as appropriate.*

B. Chemical Hazards/Controls

Hazard	Controls (Administrative, Engineered, Protective Equipment)
None.	

<u>Note:</u> *Refer to the <u>Working with Chemicals Subject Area</u> for requirements regarding particularly hazardous chemicals such as carcinogens, reproductive toxins, and highly acute toxins, including postings, decontamination plan, and address above.*

C. Environmental Hazards/Controls

Hazard	Controls (Administrative, Engineered, Protective Equipment)
Industrial waste	Indium wire and vacuum pump oils are controlled by following the hazardous waste subject area, including hazardous waste generator training and establishment of a satellite area when needed.training

<u>Note:</u> *Identify the requirements from applicable waste management subject area (<u>hazardous</u>, <u>radioactive</u>, <u>mixed</u>, <u>regulated medical</u>). List all applicable environmental permits (Suffolk County Art. XII, Title V Emission Source, etc.) and the relevant controls required by those permits.*

D. Radiation Hazards/Controls

Hazard	Controls (Administrative, Engineered, Protective Equipment)
UV lamp	Under development. When full specifications are known, Laser Safety Officer will be contacted to determine operational limits and safety procedures.

<u>Note:</u> *List sources/materials. Attach or refer to Radiation Work Permits.*

E. Biological Hazards/Controls

Hazard	Controls (Administrative, Engineered, Protective Equipment)
None.	

Note: List additional approvals/permits/reviews required (e.g., BNL Biosafety Committee approval).

F. Offsite Work Hazards/Controls

Hazard	Controls (Administrative, Engineered, Protective Equipment)
None.	

Note: List the location of all off-site work and identify any off-site organization whose ESH requirements will be followed (e.g., other DOE Labs). Indicate additional controls (not specified above) that are needed.

IV. PERFORM WORK WITHIN CONTROLS

All work shall be performed within the controls identified within this document. It is the PI's responsibility to ensure that this document is kept up to date. The PI should consult with the ERC as appropriate to determine if changes to this document are significant enough to require a new review/document.

If a hazard assessment may be required for this experiment, the PI should contact the ES&H Coordinator and/or the ERC for assistance. The PI should document any hazard assessments performed for this experiment in Section VI.

A. Training

List all project personnel, indicating they are authorized and competent to perform the work described. List the training required for each individual. Identify any certifications or experiment-specific training required. Indicate if any project personnel are minors (under 18 yrs. of age). Contact your Training Coordinator and ES&H Coordinator as appropriate for assistance.

It is the responsibility of the PI to maintain a complete up-to-date list of personnel and their full training requirements, and to ensure that training and qualifications are maintained.

Name	Life/Guest #	Required Training (Course or JTA code)
Jeremy Dodd	D6288	Electrical safety, Hazardous waste generator, Hazcom, Compressed gas, Cryogenics
Lin Jia	20649	Hazcom
Yonglin Ju	X9038	Hazcom
Pavel Rehak	13846	Hazcom
All users	N/A	Cryostat operating instructions will be developed to train users in proper use of the apparatus.

Note: The BNL Training and Qualifications Web Site contains course offerings and descriptions, required training checklist, as well as employee training records.

B. OSHA/DOE Required Medical Surveillance

Indicate if potential exposure is in excess of trigger levels listed. Exposure evaluation and/or medical surveillance may be required. Additional training may be required for any indicated agent. See the SBMS for additional information and controls on the hazards listed.

Regulated Hazard	Hazard Specific Training Trigger	Medical Surveillance Exposure Trigger
☑ None		
☐ Inorganic Arsenic	Any day above the OSHA action level (without regard to respirator use)	30 days/year above the action level (without regard to respirator use)
☐ Biohazards (CDC/NIH/WHO listed Agent)	None	See Subject Area for guidance

Regulated Hazard	Hazard Specific Training Trigger	Medical Surveillance Exposure Trigger
☐ Cadmium	Any day above the OSHA action level	30 or more days/year at or above the action level
☐ Lasers	Use Class IIIb or Class IV Lasers	Use Class IIIb or Class IV Lasers
☐ Lead	Any day above the OSHA action level	30 or more days/year at or above the action level
☐ Methylene Chloride	Any day above the OSHA action level	- 30 days/year at or above the action level - 10 days/year above the 8-hour TWA PEL or the STEL - Any time above the 8-hour TWA PEL or STEL for any period of time where an employee at risk from cardiac disease or other serious MC-related health condition and employee requests inclusion in the program
☐ Noise	Any day above the ACGIH TLV	Any time equal or greater then 85 dBA TWA 8-hour dose
☐ OSHA Regulated Chemicals *Acrylonitrile* *Benzene* *Benzidine* *1,3 Butadiene* *4-Dimethyl aminoazobenzene* *Ethylene oxide* *Ethyleneimine* *Formaldehyde* *Vinyl Chloride*	Any day above the OSHA PEL	- Routinely above the action level (or in the absence of an action level, the PEL) - Event such as a spill, leak or explosion results in the likelihood of a hazardous exposure
☐ Static Magnetic Fields	Worker who routinely works in magnetic field	- Any time at ≥ 0.5 mT (5 G) for Medical Electronic Device wearer - Any day at ≥ 60 mT (600 G) to whole body [8 hour average] - Any day at ≥ 600 mT (6000 G) to limbs [8 hour average] - Any Time at ≥ 2 T (20,000 G) to whole body [ceiling] - Any time at ≥ 5 T (50,000 G) to limbs [ceiling]

C. Emergency Procedures

Identify any emergency actions, procedures, or equipment that must be in place to insure personnel safety and environmental protection. Include the Building Local Emergency Plan, location of emergency shutoffs, and spill control materials.

None.

D. Transportation

Identify materials, hazards and controls for any on-site and off-site transportation of hazardous and/or radioactive materials. See relevant SBMS Subject Areas.

None.

E. Notifications

The PI or designee should notify building occupants of any activities that might impact them or their work, and document this here. List external personnel/organizations that require notification related to *experimental activities and/or to be notified of changes (e.g., a BNL Committee for review/approval, Occupational Medicine Clinic, Fire/Rescue).*

None.

F. Termination/Decontamination

Describe any decommissioning plan, including decontamination of the area at termination of the experiment. Identify any hazards and controls, special precautions or procedures. Include chemical and waste reconciliation. Indicate if a walk-down or an ERE will be scheduled to ensure the area is suitable for future projects. Indicate if Work Permit Form/Procedure will be used.

At the end of the work in 832, all waste materials, including regular trash, will be properly disposed of and all equipment will be removed from the work area. The work area will be restored to a condition that is acceptable to the Physics Department. Any costs with decommissioning are the responsibility of the sponsoring organization (Columbia University, Nevis Labs).

G. Community Involvement Issues

Identify issues that may require community involvement (see the Community Involvement in Laboratory Decision-making Subject Area) and describe the plan that addresses these issues. Attach the Community Involvement Checklist.

None.

V. PROVIDE FEEDBACK ON ADEQUACY OF CONTROLS AND CONTINUE TO IMPROVE SAFETY MANAGEMENT

Provide comments on the review process, including this form and communication. Identify any lessons learned or worker feedback contributing to modifications/improvements to the controls or process.

None.

VI. ATTACHMENTS

Use this section to include any supporting documents, hazard assessments, figures, tables, etc. that were not entered into the previous sections of the form.

Superconducting Magnet Division

BROOKHAVEN
NATIONAL LABORATORY

Cryogenic Safety Committee

Building 902A
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managed by Brookhaven Science Associates
for the U. S. Department of Energy

Memo

Date: November 20, 2003

To: E. Lessard

From: Richard Thomas, former Chairman, Cryogenic Safety Committee

Subject: Minutes of the CSC Meeting of 01 May 2003

I asked the former secretary of the CSC whether he could send me draft minutes of the 01 May 2003 meeting, and he provided them to me yesterday. I have reviewed and edited his minutes.

Normally, these minutes (which are still "draft" minutes) would have been sent to the members of the committee for review before being distributed.

There is no significant difference in the list of action items from those items that appeared in the earlier emails.

Superconducting Magnet Division

BROOKHAVEN
NATIONAL LABORATORY

Cryogenic Safety Committee

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managed by Brookhaven Science Associates
for the U. S. Department of Energy

Memo

Date: May 1, 2003

To: Distribution

From: Richard Thomas, Chairman, Cryogenic Safety Committee

Subject: Minutes of the CSC Meeting of 01 May 2003

Review of the Nevis Liquid Helium e-Bubble Chamber and its Cryostat — Meeting 1

Members Present: Richard Thomas *(Chairman)*, M. Gaffney *(ex-officio)*, M. Iarocci, S. Kane, P. Kroon, P. Mortazavi, M. Rehak, and K. C. Wu

Members Absent: None

Others Attending: J. Muratore *(Recording Secretary)*, Jeremy Dodd (Nevis), Yonglin Ju (Nevis), Pavel Rehak (Physics), J. Sondericker, Bill Willis

The meeting was called to order by the chairman at 1:30 pm in Conference Room 63 of Building 902. Representatives of the Nevis Electron Bubble Chamber Group, Jeremy Dodd and Yonglin Ju, were present.

Review of the Nevis Liquid Helium e-Bubble Chamber and its Cryostat

The purpose of this meeting was to review the electron bubble chamber, a prototype for a future neutrino detector, its liquid helium/liquid nitrogen cryostat, and the associated storage dewars for LHe and $_{LN2}$, He gas cylinder, plumbing, and valves. The presentation was given by Jeremy Dodd and it followed a set of printed copies that were given to committee members. The printed handout included schematics of the chamber, cryostat, and other hardware, but did not include a complete P&ID drawing.

The chamber will use liquid helium or liquid neon, and it is built by Nevis Lab at Columbia University. The cryostat in which it is housed is supplied by Janis, and the storage dewars and valves are also vendor-supplied.

The test chamber is double-walled and made of type 304 stainless steel. Two copper cooling coils are welded to the flanges of the test chamber. The chamber has five sapphire optical windows and a number of high voltage and low voltage cable feed-throughs. It was designed to meet ASME pressure vessel code for 150 psi but maximum operating pressure will be only 30 psi. The results of ANSYS calculations for a pressure equal to 150 psi gave a maximum stress that was six times lower than the allowable 129 MPa. The chamber has been pressure-tested to about 40-50 psi.

Information was then given about the cryostat and dewars and other associated hardware supplied by the vendor, Janis, and asserted by them to meet code requirements.

Results of an ODH calculation for Building 832 High Bay area (6000 cubic meters volume), where the experiment will be housed, resulted in an unclassified rating under the worst case scenario.

During the course of the presentation, a number of questions were raised by committee members.

The chamber pressure test was done without witnesses and has no verification. Also it was not done to design pressure.

The LN_2 vessel is open. There appear to be three ports to the LN_2 vessel. It isn't clear why this is the case, since one would normally expect only a "fill" port and a "vent" port. It was noted that these ports should not be left open to air, since doing so can result in ice blockage of the vent(s). Also, when left open to air, oxygen enrichment of the liquid nitrogen is possible. A check valve should be used on the vent port and the other ports closed when not in use, unless more than one port must be allowed to vent in order to get adequate flow should there be a catastrophic loss of vacuum. In that case, check valves should be placed on each port.

No document from Janis was presented to certify that the cryostat and its vessels were indeed designed for use at 150 psi. The committee also questioned whether the feedthroughs were good to the same design pressure (150 psi) as the chamber. A witnessed pressure test must be performed and the proper operation of the relief valves must be verified. Also, it needs to be determined whether the 150 psi design pressure is psia or psig.

The sizing of the relief valves was questioned. These were given as 0.5" and are supplied by Janis. Details of sizing rationale were not available at the meeting.

Relief valve lines that connect to the pumping ports (for vapor cooling) are not vacuum-jacketed. This may cause icing on the lines, including icing of the relief valves. Proper operation of the relief valves might be impaired. Whether this is a problem or not depends on the temperature that can be reached at the relief valves when pumping on the bath.

There is no complete P&ID drawing, so it can not be determined whether every volume that can be closed off has a proper relief valve.

S. Kane expressed concern that the fusion welds (most welds are of this type) may not be adequate and would like to see detailed drawings.

Before routine operation of the cryostat begins, the operating procedures must be determined to meet present standards. If the cryostat is to be unattended overnight during several-day operations, the procedures shall indicate how to insure safety during such a run.

Recommendations:

Approval is recommended contingent on a satisfactory resolution of the following outstanding issues:

1) The LN_2 vessel should not be open to air and should instead be equipped with one or more check valves.
2) Additional material on the calculations used by Janis in determining the relief valve sizing is to be provided to the committee. Verify that the ½-inch relief valves are adequate.

3) A verified pressure test of the bubble chamber should be performed. This can be done by the Physics Safety Review Group. (The pressure test should be appropriate for a vessel with a design pressure of 150 psi. The test pressure actually depends on resolving the psia/psig question.) At the time of this pressure test, also verify that the relief valves open at the set pressures.
4) If the two pumping ports connected to the vapor-cooling circuit are not vacuum-jacketed, determine whether there is a risk of condensation and ice build-up on the relief valves when the bath is pumped under humid conditions.
5) A detailed P&ID drawing of the entire system shall be provided and reviewed. The P&ID must show all valves, including relief valves, and all volumes that can be closed off.
6) Verify that the feedthroughs are good to the design pressure, 150 psi.
7) Detailed drawings for the welds, including those for the feedthroughs, shall be supplied.
8) Certifications for the cryostat and other hardware certification shall be obtained from Janis.
9) Written operating procedures shall be produced and reviewed. The procedures need to address safe operation when the cryostat is operated for several days and left unattended overnight.

It was agreed that the items above may be satisfied without another full committee meeting by submitting the information requested to the CSC for review. One or more CSC members will be asked to verify that the relief-valve sizing calculations are correct, that the P&ID drawing is complete and does not raise issues regarding trapped volumes, that the drawings of the fusion welds show them to be satisfactory, and that the operating procedures meet current standards. Once a majority of the CSC members are satisfied that all the conditions above have been met, approval is recommended.

The meeting was adjourned at approximately 4:30 p.m.

Approved: ______________________________

Richard Thomas, Chairman, CSC

rt/jm

Attachments

Distribution:

J. Tarpinian
Members of the Cryogenic Safety Committee
J. Dodd, Y. Ju
E. Lessard

LESHC Follow-up Review of the Electron Bubble Chamber

Nevis Laboratories, Columbia University
& Brookhaven National Laboratory

Presented to the BNL LESHC
Cryogenic Safety Sub-Committee
November 21, 2003

Objective of project

- To study, design and develop a new electron-bubble ("e-Bubble") detector, using cryogenic liquid (He, Ne) as the detecting medium, for the detection of low-energy particle tracks from neutrino sources such as the Sun, and from accelerator facilities
- Interesting condensed matter physics also
- The purpose of this system is to measure many of the basic properties of e-Bubbles in these liquids, to find the parameters that allow good spatial and energy resolution on track segments, and determine the feasibility of constructing a modest-size tracking chamber that in turn would lead to a study for a large detector for neutrinos and other applications

Requirements for test chamber

- Five windows transmitting from IR to UV
- HV and signal feedthroughs
- Range of temperatures (down to ~2K) and pressures (several atmospheres)
- Field cage to provide uniform E field
- Photoelectric source for accurately timed current pulses
- And later, alpha and fission (densely-ionizing) sources

Current personnel

- From Nevis/Columbia:
  - Jeremy Dodd, Yonglin Ju, Misha Leltchouk, Bill Willis
  - Richard Friedberg, Tony Heinz
  - plus students
- From BNL:
  - Valeri Tcherniatin, Lin Jia, Veljko Radeka, Pavel Rehak, John Warren
  - Support/help from Tom Muller and his team in Building 832

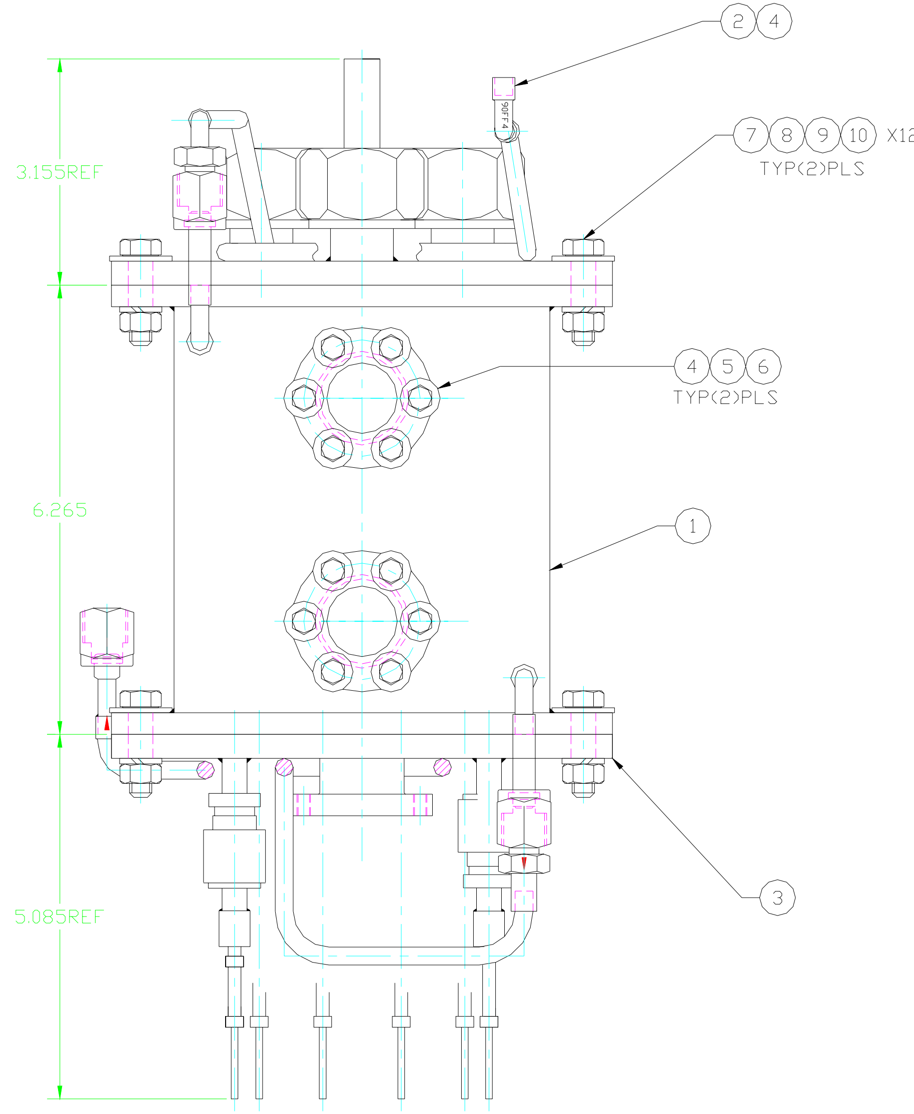
Experimental setup

- LHe e-Bubble Test Chamber (Nevis and BNL)
- LHe/LN_2 Cryostat with relief valves (Janis)
- LHe Dewar and LN_2 Dewar (Chart)
- Helium gas bottle
- Vacuum pumping stations and pumping lines
- Temperature sensors and heaters
- Pressure gauges, vacuum gauges and flow meters
- High voltage cables and feedthroughs
- Electrode structure and (later) radioactive sources
- Electronic readout
- Optical measurement sub-systems (later)
- Safety sub-systems (relief valves, oxygen monitor, etc)

e-Bubble chamber specification
(L. Jia and L. Addessi)

- Double-walled LHe vessel, volume about 1.5 liters
- Designed to stand an internal pressure of 10bar (150 psi). The max. pressure in our experiments currently set at 30 psi
- Hydrostatic pressure test (220 psi) passed successfully (see later)
- Relief device (30 psi) installed at top of the central tube
- Two copper cooling loops for the helium vapor-cooling circuits are soldered on the flanges of test chamber. A needle valve is used to supply and control the flow rate in the helium vapor-cooling circuit
- Contains a Teflon frame with high voltage ring electrodes (up to 10kV). Ten high voltage cables inserted through bottom flange. Each SS conductor wire is electrically insulated by a Teflon sleeve of 3mm outer diameter
- Four low voltage (signal) ports on the top flange

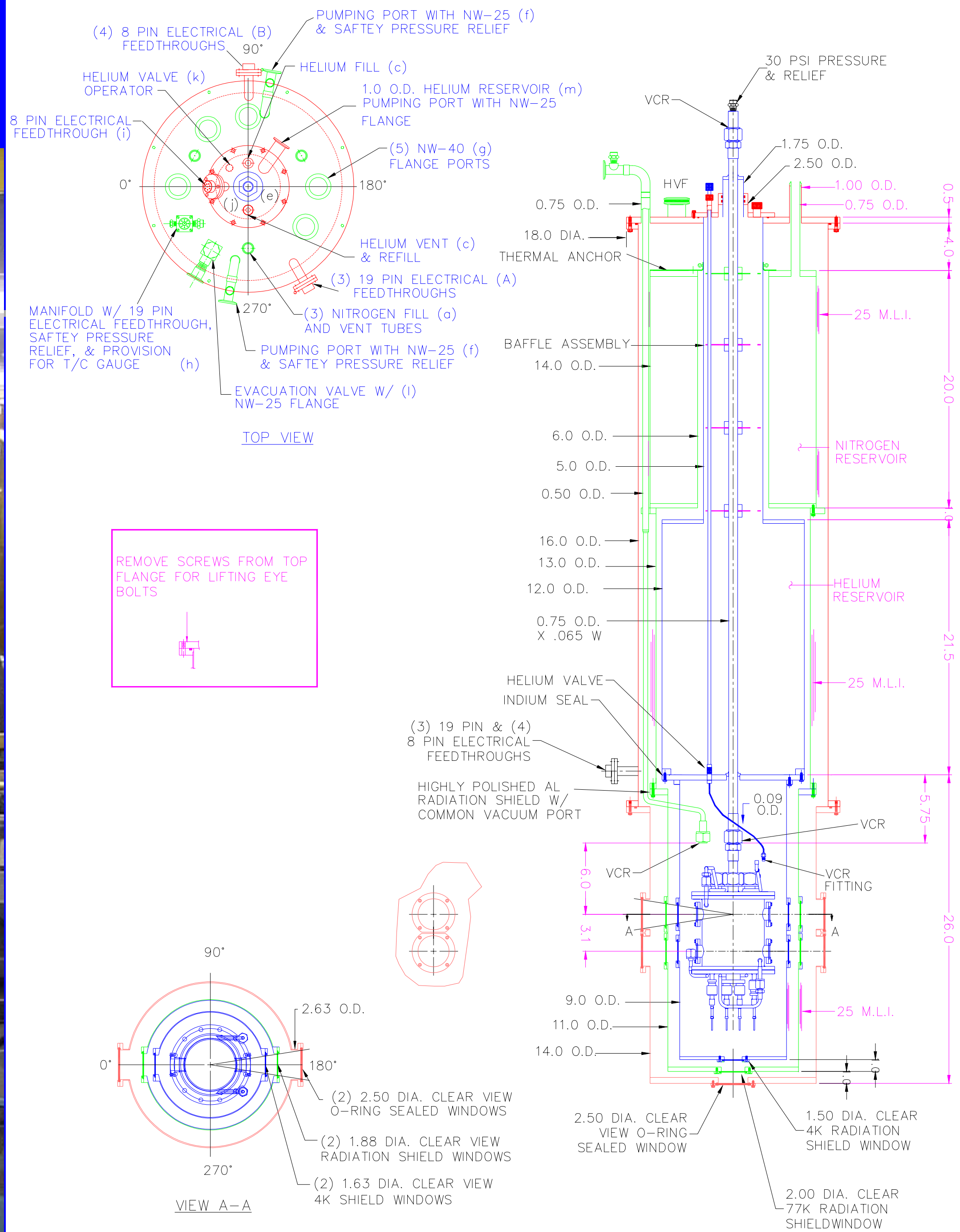
e-Bubble chamber



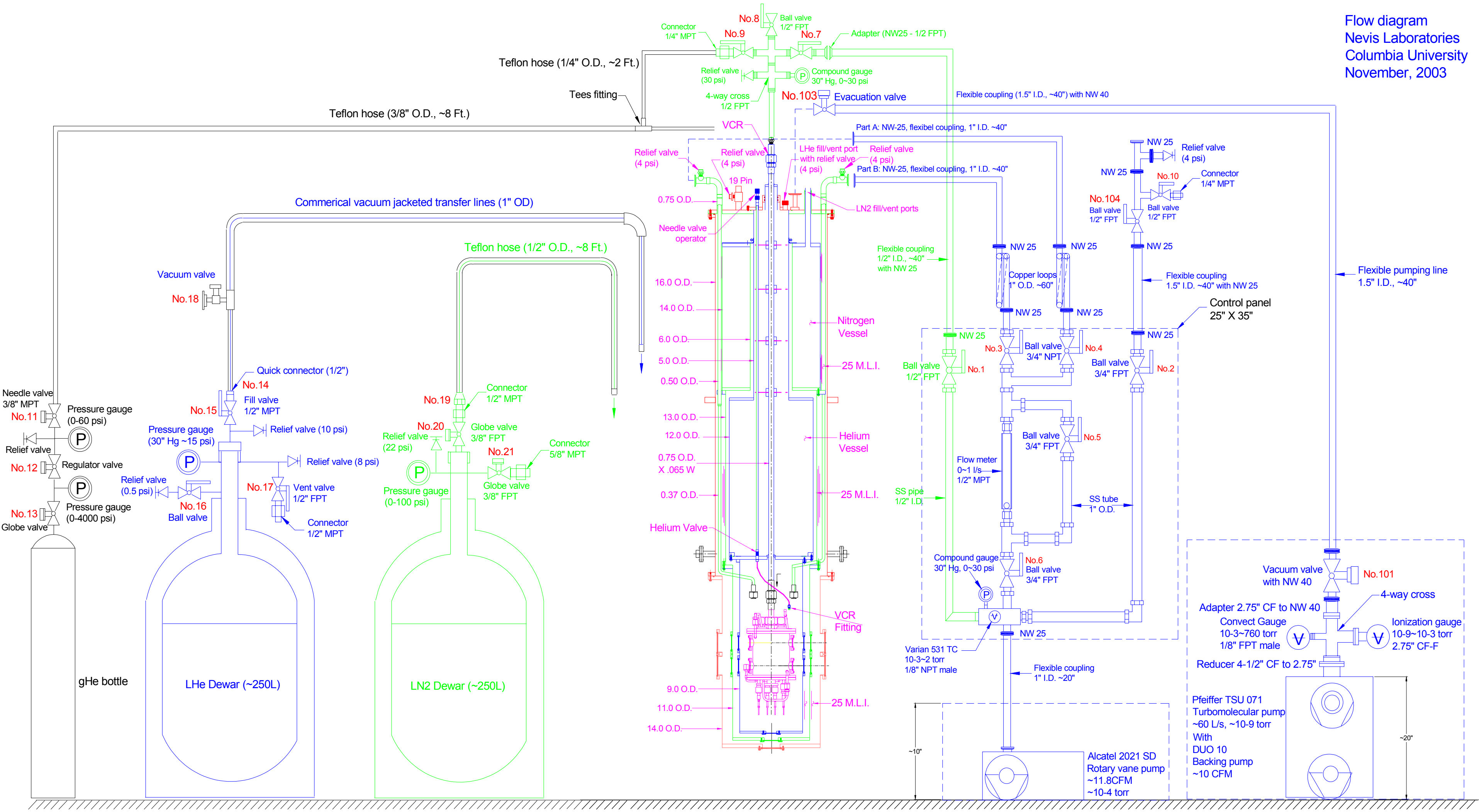
LHe/LN_2 cryostat

- Provides 4.2K environment, contains the test chamber and provides helium vapor cooling (2.2~4.2K) to the test chamber
- Contains the vacuum jacket, LHe vessel and LN_2 vessel, which are disassembled to gain access to the test chamber
- Includes 5 relief valves (4 psi) for vacuum jacket (1), LHe vessel (2), cooling circuit loops (2), located on the top flange of cryostat
- LN_2 vessel cannot be sealed
- Two radiation heat shields (77K and 4.2K) are thermally attached to the LHe and LN_2 vessels, respectively
- Four optical windows at the sides and one at the bottom of the vacuum chamber and each heat shield
- About 45 liters for LHe vessel and 41 liters for LN_2 vessel. The holding time of LHe and LN_2 is about 3 days

LHe/LN$_2$ cryostat



P&ID for pump/fill lines



ODH calculation and classification

Examined five scenarios for their ODH risk:

1. Normal boil-off operation of 250L LHe dewar and LN_2 dewar
2. Normal boil-off operation of 45L LHe vessel and 40L LN_2 vessel in the cryostat (at least 3 days)
3. Assuming 45L LHe vessel in cryostat broken, vacuum lost
4. Assuming 40L LN_2 vessel in cryostat broken, vacuum lost
5. Assuming 1L LHe EBC in cryostat broken, vacuum lost

Calculation results (see documentation):

- Fatality factor: 3×10^{-6}
- Fatality rate $< 10^{-9}$
- ODH class = 0

Items from May 1 Review

1. The issue of the three open ports on the LN2 vessel
2. Check vent-rate scenarios studied by Janis in determining the size of the vendor-installed relief valves
3. Prepare test plan (and witnessing) for eBubble chamber 200 psi pressure test and test of relief valves
4. Work with Physics ESR (Ron Gill) to develop plan/procedures for leaving cryostat unattended
5. Check whether the two pumping ports connected to the vapor-cooling circuit are vacuum-jacketed
6. Make complete P&ID drawing for whole system
7. Determine pressure rating for the feedthroughs, and provide detail of the associated welds
8. Provide more detail on the welds of the eBubble chamber, including providing a complete set of drawings
9. Determine whether the Janis cryostat is built to code

Also included:

10. BNL Physics Department ESR Form and Approval

1. The three open ports on the LN2 vessel

- We propose to add lengths of rubber tubing to each of the three ports

"The risk is minimal. You can prevent it by adding Bunsen type valves (rubber tubes with a slit for venting and sealed with a stopper), simple rubber tubes long enough to make a U-turn and end up pointing downwards."

M. Jirmanus, Janis, 10 May, 2003

2. Check vent-rate scenarios studied by Janis, and sizing/capacity of relief valves

- In May, we had examined the venting rates under a variety of failure modes of the cryostat (see ODH documentation). For the "worst-case" scenario of loss of vacuum, we calculated the expected flow rates, compared to the max. mass flow rates through the respective relief valves:

	Mass flow rate under loss of vacuum (kg/sec)	Max. mass flow rate through relief valves (kg/sec)
LHe reservoir	0.379	0.604
LHe chamber	0.037	1.007
LN2 reservoir	0.043	0.338

- Calculated flow rates < relief valve capacities

2. Check vent-rate scenarios studied by Janis, and sizing/capacity of relief valves

- Since May, we have been working with K.C. Wu to gain a more complete understanding of the relief valve capacities, with a particular emphasis on the LHe reservoir
- LHe reservoir relief valve (Generant, VRV-250BB-4) specifications obtained from vendor, along with flow-rate calculator
- Also confirmation from Janis that the LHe reservoir should be able to withstand up to 4 atmospheres internal pressure
- On the basis of this new information, K.C. approves the relief system for the experiment (30 Oct, 2003)

3. Prepare test plan for eBubble chamber pressure test and test of relief valves

- Since June we have been working with Steve Kane in preparation for a hydrostatic test of the chamber
- Steve requested further studies on the chamber flanges, on which we were helped by R. Alforque and C. Pai (FEA) – thank you!
- 30 September memo from Steve to R. Travis confirming ASME compliance
- With these studies in hand, hydrostatic test of chamber to 220 psi, and of jacket to 30 psi, passed successfully on 27 October, 2003 (first attempt failed due to incorrectly assembled indium seals)
- T. Monahan memo # SE88SR02 issued 12 November
- Witnessing of relief valve tests <u>still to be done</u>

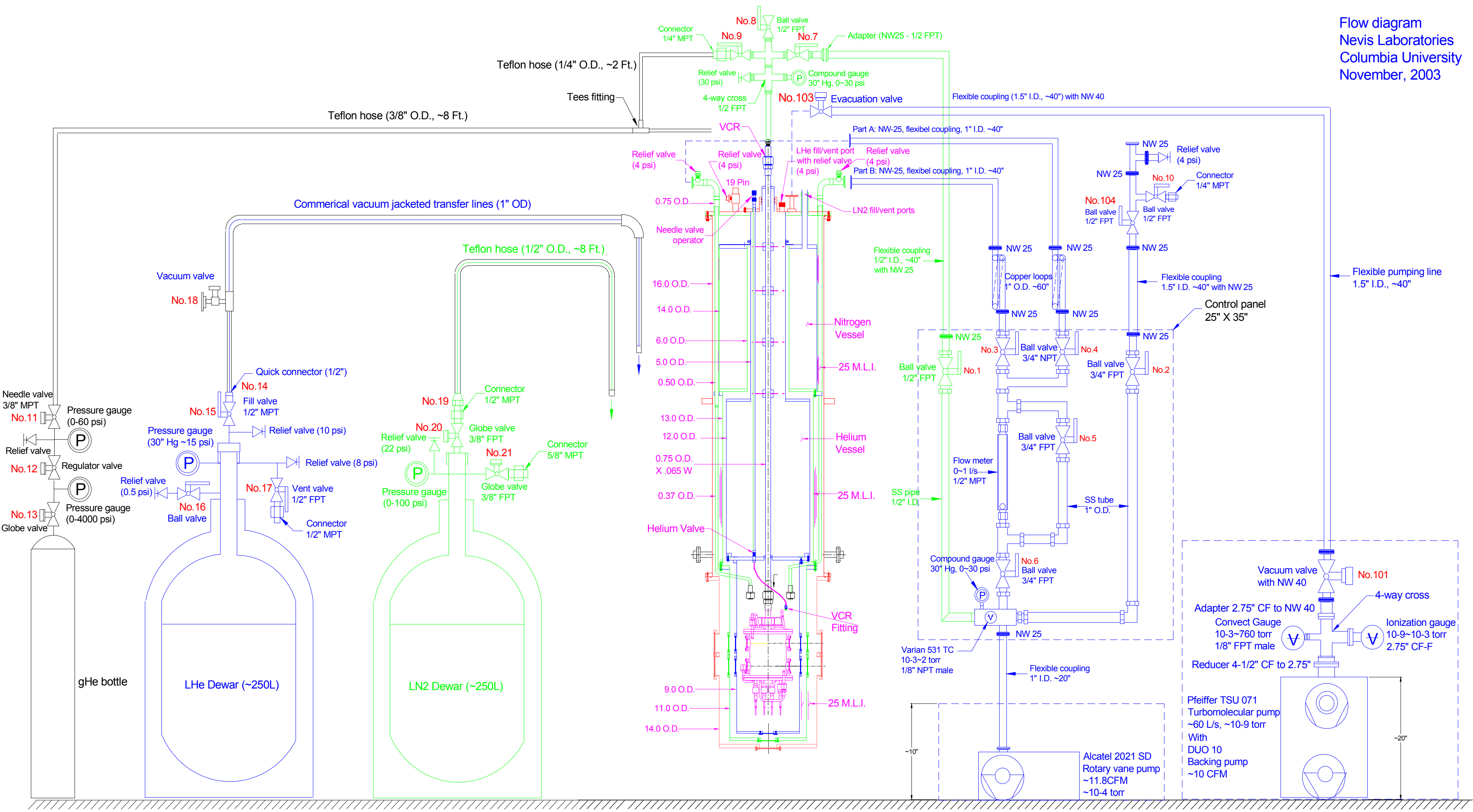
4. Work with Physics ES&H to develop procedure for leaving cryostat unattended

- Discussions with Ron Gill (Physics ES&H Coordinator) and Tom Muller (832 Building Manager)
- Agreement to add ‘Caution’ signage to experimental area, indicating that cryostat contains liquid, when left unattended (e.g. overnight)
- We plan on taping off area also

5. Check whether two pumping ports for vapor-cooling circuit are vacuum-jacketed

- Relief valves on both pumping ports
- Pumping ports are not vacuum-jacketed
- Maximum flow rate is small:
  - Pumping volume is only the volume between the two (cylindrical) chamber walls
  - Capillary (0.093” OD) feedline from LHe reservoir to cooling circuit
- Pump on one (of two) ports – no flow through other port

6. Provide complete P&ID drawing



7. Determine pressure rating for feedthroughs, and provide weld details

- Two types of (Ceramaseal) feedthroughs:
  - HV (single-conductor) – rated to 1,000 psig
  - Signal/LV (eight-conductor) – rated to 250 psig
- (Fusion) weld details have been provided to S. Kane
- Specs for VCR fittings also provide to Steve
- Steve has approved all of the above

8. Provide details of chamber welds, and complete set of drawings

- Complete set of drawings provided to CSC Chair in May, and to S. Kane
- Welds (see drawing WA-1-4-E) are 0.1” fillet welds using 316L SS filler rod
- Two fusion welds where the SS elbows and tubes of the LHe cooling circuit are joined
- Feedthroughs have fusion welds (also Item 7.)

9. Determine whether Janis cryostat built to code

- Vacuum vessel designed to ASME code, but not stamped
- Central fill tube designed to ASME code, to withstand 150 psi
- “The reservoirs are not designed to ASME code because this would contradict the cryogenic requirements of the unit (…). These reservoirs are not vacuum vessels, and they operate at atmospheric pressure or slightly over.”

M. Jirmanus, Janis, 10 May, 2003

10. Physics ESR Approval

- Approved 16 June, 2003, pending two items:
  - Specifications of UV pulser lamp required (provided 24 June)
  - Approval by CSC

Project: Novel Electron Bubble Particle Detector

Procedure for Operating Columbia (Nevis) LHe Electron Bubble Chamber Cryostat

Version 1.1

Hand Processed Changes

HPC No.	Date	Page No.	Initials

Approved:______________________________**Date:**______________

PROCEDURE FOR OPERATING NEVIS LHE EBC

1. Purpose

1.1 This Operating Procedure Manual provides instructions for operation of the Columbia (Nevis) LHe Electron Bubble Chamber (EBC) System, with explanation of the LHe/LN_2 Cryostat and associated infrastructure involved.

1.2 The Operating Procedure set forth here is required for the safety of the system and of the operators. All participants in the operations must study the Operating Procedure Manual.

1.3 The Log Book for operations must indicate which version of the Operating Procedure Manual is being followed at the time; who is in charge of operations at any given time (Chief); and who else is assisting. All significant conditions in the system and changes must be noted in the Log Book.

2. Responsibilities

2.1 It is the Chief operator's responsibility to ensure that all operators have the appropriate training, and that all procedures in this Manual are followed.

3. Prerequisites

3.1 All operators must have received the required BNL Training prior to working with the LHe EBC system, and have studied this Operating Procedure manual.

4. Precautions

4.1 Be sure that all necessary system components are functioning correctly prior to start-up.

5. Procedure

5.1 BEFORE START-UP

5.1.1 Make sure that the **LHe vacuum jacketed transfer line** is not installed.

5.1.2 Be sure that **all valves** (vacuum, ball, globe) except **ball valve 16** on the **LHe Dewar** are closed, and that all relief valves are installed on the **LHe Dewar, LN_2 Dewar, Pumping port** and **Cryostat.**

5.1.3 Do not open any valves if there is below 0 (psig) pressure indicated on the **pressure gauges P4 and P5** on the **LHe Dewar and LN_2 Dewar.** This would allow air to rush into the Dewar and form an ice plug.

5.1.4 Be sure to wear safety glasses and insulated gloves when handling liquid helium and nitrogen.

5.2 EVACUATION OF LHE/LN_2 CRYOSTAT VACUUM JACKET

5.2.1 Connect the flexible coupling from the **turbo-pump** to the **connector of vacuum valve 103** extending from the Cryostat.

5.2.2 Open **vacuum valve 101** on the top of **turbo-pump**, turn on the **turbo-pump**, and evacuate the flexible coupling for several seconds.

5.2.3 Open **vacuum valve 103**, evacuate the cryostat vacuum jacket until the pressure at the pump drops to **1×10^{-5} torr or less,** as measured by the **ionization gauge**. It is recommended to evacuate the system overnight before operating.

5.2.4 Close firmly **vacuum valve 103,** turn off the **turbo-pump,** and close **vacuum valve 101.**

5.2.5 Re-evacuation is required when cryogen hold times begin to decrease or condensation becomes noticeable on the lower vacuum jacket during operation.

5.2.6 Do not introduce cryogen into the chamber with the evacuation valve open. This may cause cryopumping of vacuum pump oils into the Cryostat vacuum jacket.

5.3 PUMP/PURGE CENTRAL TUBE AND e-BUBBLE CHAMBER

5.3.1 Connect the **helium gas transfer line** (Teflon tube) to the **connector** of **needle valve 11** on the **gHe bottle.** Connect the other end of the **helium gas transfer line** to **the connector** of **ball valve 9.**

5.3.2 With the Cryostat at room temperature, open **ball valve 1** on the control panel. This connects the **mechanical pump** to the **central tube**.

5.3.3 Turn on the **mechanical pump**, and evacuate the pumping line for several seconds. Open **ball valves 7 and 9**, and evacuate the **central tube, e-Bubble chamber** and **helium gas transfer line** until the pressure drops to below **1 torr,** measured by the **thermocouple vacuum gauge TC.**

5.3.4 Close **ball valves 7, 9 and 1,** and turn off the **mechanical pump.**

5.3.5 Open **globe valve 13** and set **regulator valve 12** at **15 psig.** Open **needle valve 11** and **ball valve 9**, allowing helium gas into the **central tube.**

5.3.6 After 30 seconds, close **ball valve 9**, **the central tube** is now pressurized (15 psig).

5.3.7 Open **ball valve 8**, release helium gas out off the **central tube,** make sure that the pressure is slightly higher (1~2 psig) than atmospheric pressure by checking **pressure gauge P2** on the top of central tube, then close **ball valve 8.**

5.3.8 Repeat the above pump and purge procedures (5.3.2 through 5.3.7) 2-3 times. Stop after step 5.3.6 on the last cycle, so that the **central tube** and **e-Bubble chamber** are filled with pressurized pure helium gas (15 psig).

5.3.9 Close **ball valves 7, 8 and 9.** Close **globe valve 13, regulator valve 12 and needle valve 11.**

5.3.10 Disconnect and remove the **helium gas transfer line** from **the connector** of **ball valve 9.** Keep the **helium gas transfer line** on the connector of **needle valve 11** of the **gHe bottle.**

5.4 PUMP/PURGE LHe VESSEL

5.4.1 Never evacuate the **LHe vessel** unless the **Cryostat vacuum jacket** has been previously evacuated, collapse of the **LHe vessel** wall may occur.

5.4.2 Connect the **helium gas transfer line** to **the connector** of **ball valve 10.** Open **ball valve 2** on the control panel. This connects the **mechanical pump** to the **LHe vessel.**

5.4.3 Plug in **mechanical pump**, and evacuate **pumping line** for several seconds.

5.4.4 Open **ball valves 104 and 10**, and evacuate **helium gas transfer line** and **LHe vessel** for several minutes to remove any air or moisture.

5.4.5 Open the **helium needle valve 105**, and evacuate the path through the **needle valve, capillary tube** and **cooling circuit loops.**

5.4.6 Close **ball valves 104 and 2,** and unplug the **mechanical pump.**

5.4.7 Open **globe valve 13** and set **regulator valve 12** (on the gHe bottle) at **4 psig.**

5.4.8 Open **needle valve 11**, allowing helium gas into the **LHe vessel.**

5.4.9 After 30 seconds, close **helium needle valve 105.** Close **ball valve 10**. The **LHe vessel** is now pressurized (4 psig).

5.4.10 Close **globe valve 13, regulator valve 12 and needle valve 11.** Keep the **helium transfer line** on **the connector** of **ball valve 10.**

5.4.11 Be sure to seal **helium fill port C1** and close **ball valve 22** on **helium vent port C2** on the **LHe vessel** after removing the vacuum pump, to prevent air and moisture from entering the vessel.

5.5 PRECOOLING LHe VESSEL WITH LN_2

5.5.1 Connect a **Teflon transfer hose** to the **quick connector 19** on the **LN_2 Dewar.**

5.5.2 Insert the other end of the **Teflon transfer hose** though the **helium fill port (C1)** into **LHe vessel** until it reaches the bottom.

5.5.3 Open **globe valve 20** on the **LN_2 Dewar**, this valve can be adjusted to obtain the proper liquid flow rate.

5.5.4 Open **ball valve 22** on the **helium vent port (C2). Liquid nitrogen** will be transferred into the **LHe vessel** directly from the pressurized **LN_2 Dewar**, while venting out through the **helium vent port (C2).**

5.5.5 During this cool down, open occasionally the **helium needle valve 105**, by approximately one full turn, to let **liquid nitrogen** enter the **needle valve, capillary tube, and cooling circuit loops.** This procedure also prevents the needle valve from freezing shut as it is being cooled along with the rest of the **LHe vessel.**

5.5.6 Approximately **4~5 liters** of **liquid nitrogen** is sufficient to precool **LHe vessel.**

5.5.7 Check **temperature sensors T1 and T3**, to make sure that the temperature difference between them is less than 10K.

5.5.8 When the **liquid nitrogen** transfer is complete, close **globe valve 20** on the **LN_2 Dewar.** Remove the **Teflon transfer hose** from **helium fill port (C1)** on the **LHe vessel.**

5.5.9 Seal **helium fill port (C1),** and close **ball valve 22** on the **helium vent port (C2)**, to prevent air and moisture from entering **LHe vessel**, while venting though relief valves.

5.5.10 Keep the **Teflon transfer hose** on the **quick connector 19** of the **LN_2 Dewar.**

5.6 LIQUID NITROGEN FILLING TO LN_2 VESSEL

5.6.1 Insert the **Teflon transfer hose** though one of the **nitrogen fill/vent ports (A1)** into the **LN_2 Dewar** until it reaches the bottom.

5.6.2 Open **globe valve 20** on the **LN_2 Dewar**, this valve can be adjusted to obtain the proper liquid flow rate.

5.6.3 **Liquid nitrogen** will be transferred into **LN_2 vessel** directly from the pressurized **LN_2 Dewar**, while venting though the other two **nitrogen vent ports (A2 and A3).**

5.6.4 Approximately **40~45 liters** of LN_2 is needed for this cool-down and fill.

5.6.5 When the **liquid nitrogen** starts to be visible from one of the **nitrogen vent ports (A2 or A3)**, close **globe valve 20** on the **LN_2 Dewar.**

5.6.6 Record readings on **temperature sensors T10 and T11** periodically during steps 5.6.3 through 5.7.1.

5.6.7 Remove the **Teflon transfer hose** from **nitrogen fill/vent tubes (A1)** on the **LN_2 vessel.** Remove the **Teflon transfer hose** from the **quick connector 19** on the **LN_2 Dewar.**

5.7 REMOVE LN_2 FROM LHe VESSEL

5.7.1 Wait and allow **liquid nitrogen** to completely cool the **LHe vessel** and **e-Bubble chamber** to liquid nitrogen temperature (several hours) by checking **temperature sensors T4, T5 and T6** are all less than 90K.

5.7.2 Insert a **Teflon tube** though the **helium fill port (C1)** into **LHe vessel** until it reaches the bottom.

5.7.3 Open **globe valve 13** and set **regulator valve 12** (on the gHe bottle) at 4 psig. Open **needle valve 11** and **ball valve 10.** Admit warm gas helium from the **gHe bottle** into the **LHe vessel** by over-pressuring it.

5.7.4 Close **ball valve 22** on the **helium vent port (C2)**, to allow pressurization (relief valves limit over-pressure to 4 psig).

5.7.5 **Liquid nitrogen** will start flowing out of this tube once the **LHe vessel** is pressurized. The **liquid nitrogen** outflow should be transferred to a suitable container (e.g. a bucket).

5.7.6 Continue this process for about 5 minutes until it appears that no **LN_2** is flowing out off the **Teflon tube.** Note that solid nitrogen has a very large heat capacity (an order of magnitude greater than copper), so even an inch left at the bottom of the vessel will require large amounts of liquid helium to cool to 4.2K.

5.7.7 During this process, check **temperature sensor T1** and wait until it is higher than **100K.**

5.7.8 Remove the **Teflon tube** from the **LHe vessel** and seal the **helium fill port (C1).**

5.7.9 Close **ball valve 10, globe valve 13, regulator valve 12** and **needle valve 11.**

5.7.10 Keep the **helium gas transfer line** on **the connector** of **ball valve 10.**

5.7.11 Keep the **helium transfer line** on the connector of **needle valve 11** of the **gHe bottle**.

5.8 PUMP/PURGE LHe VESSEL AND e-BUBBLE CHAMBER COOLING CIRCUIT

5.8.1 Open **globe valve 13** and set **regulator valve 12** (on the gHe bottle) at **4 psig**.

5.8.2 Open **needle valve 11** and **ball valve 10**, fill **LHe vessel** with helium gas from **gHe bottle.**

5.8.3 After about 30 seconds, close **ball valve 10**, **LHe vessel** is now pressurized (4 psig). Look and listen for escaping gas, and fix any leaks detected.

5.8.4 Open **ball valve 2** on the control panel, turn on **mechanical pump**, and evacuate **pumping line** for several seconds.

5.8.5 Open **ball valve 104**, and evacuate the **LHe vessel** for several minutes to remove final traces of **LN_2.** Open also **ball valves 3 and 6**. During this process, open **helium needle valve 105**. This evacuates the path through the **needle valve, capillary tube, cooling circuit loops** and **pumping ports.**

5.8.6 Once the pressure drops to 0.1 torr, measured on the **thermocouple vacuum gauge TC,** close **ball valves 104, 2, 3 and 6.** Turn off the **mechanical pump.**

5.8.7 Repeat the above pump and purge procedures (5.8.2 through 5.8.6) 2-3 times. Stop after step 5.8.3 on the last cycle, so that the **LHe vessel** and **cooling circuit loops** are filled with pressurized pure helium gas (4 psig).

5.8.8 Close **globe valve 13, regulator valve 12** and **needle valve 11.**

5.8.9 Remove the **helium gas transfer line** from **the connector** of **ball valve 10.**

5.9 LIQUID HELIUM FILLING TO LHe VESSEL

5.9.1 Check that the pressure in the **central tube** and **e-Bubble chamber** is still above 15 psig, using **pressure gauge P2**. If it is not, follow the gHe back-filling procedure in step 5.3.5 until the pressure reaches 15 psig.

5.9.2 During this operation, maintain the pressure inside the **central tube at** 15 psig by setting **regulator valve 12** at 15 psig, and keeping **valves 9, 11 and 13** open.

5.9.3 Before beginning to transfer liquid helium, be sure that the vacuum jacket of the **LHe transfer line** has been properly evacuated. Periodic re-evacuation of the transfer line jacket is necessary for efficient LHe transfer.

5.9.4 Purge the **LHe transfer line** with gaseous helium.

5.9.5 Insert quickly the **LHe transfer line** to the bottom of the **LHe vessel** through the **helium fill port (C1).**

5.9.6 Close **ball valve 16** on the **LHe Dewar**. Remove the plug of **quick connector 14** on the **LHe Dewar**, place the end of the **LHe transfer line** into **quick connector 14** and insert it until it touches **fill valve 15** on the **LHe Dewar.**

5.9.7 Open **fill valve 15** and insert the **LHe transfer line** to the bottom of the **LHe Dewar,** tighten **quick connector 14.**

5.9.8 Open **ball valve 22** on the **helium vent port (C2).** The boil-off caused by the warm **LHe transfer line** being inserted into the **LHe Dewar** will cause immediate pressure rise and transfer **liquid helium** into the **LHe vessel.**

5.9.9 Set the initial transfer rate of **liquid helium** at a very slow rate, by regulating the pressure in the **LHe Dewar** (in the range 1-2 psig). This guarantees that no liquid helium is accumulated in the **LHe vessel** until the **temperature sensor T3** at bottom of 4K-heat shield is cooled below 20K.This slow transfer makes more efficient use of the enthalpy of the liquid helium as it cools the **LHe vessel** and the attached **radiation shield.**

5.9.10 Check **temperature sensors T1 and T3** periodically, to make sure that the temperature difference between the two is less than 7K.

5.9.11 During the liquid helium transfer, plug in the **mechanical pump.** Open **ball valves 3 and 6** on the control panel, at which point the **mechanical pump** should start to "gurgle", indicating that the **helium gas** is entering the **pumping port (F1).**

5.9.12 Open and close **helium needle valve 105** several times, to clear the path through **needle valve and capillary tube** and let **liquid helium** enter the **cooling circuit loops** for **e-Bubble chamber** cooling. Leave **needle valve 105** closed at the end of this operation.

5.9.13 After several minutes the pump should become quiet, close **ball valves 3 and 6,** turn off the **mechanical pump.**

5.9.14 When **temperature sensor T3** at the bottom of the 4K-radiation heat shield has cooled down to approximately 9K, the helium transfer rate can be accelerated and the cryostat filled completely with liquid helium.

5.9.15 At the final phase of **liquid helium transfer**, **helium needle valve 105** is fully opened to allow the **liquid helium** to enter the **cooling circuit loops.**

5.9.16 Check the helium level meter occasionally. The **LHe vessel** is completely filled (21" on the level meter) using ~ 50 liters of **liquid helium** for cool down and fill.

5.9.17 It is important not to keep the helium level meter on except when you need to record the level to avoid the extra heat load to the LHe vessel.

5.10 AFTER LIQUID HELIUM FILLING

5.10.1 Upon completion of **LHe** transfer, the **temperature sensor T3** at the bottom of 4K-radiation heat shield should stabilize at about 8.1K.

5.10.2 Wait a few minutes for the helium boil-off to settle down, and then lift the **LHe transfer line** until it just clears **fill valve 15**, then close it.

5.10.3 Open **ball valve 16**, and **LHe Dewar** is only venting from the relief valve (0.5 psig).

5.10.4 Remove the **LHe transfer line** from the **helium fill port (C1)**, seal the **helium fill port (C1),** and close **ball valve 22** at the **helium vent port (C2),** to prevent air from entering the **LHe vessel.** The helium vapor should now be venting out of the relief valves.

5.10.5 Remove the line completely from the **LHe Dewar,** plug in **quick connector 14.**

5.10.6 The pressure relief valves are usually set to vent at a pressure of 4 psig. This maintains a positive pressure inside the **LHe vessel** which prevents air entering the vessel, while maintaining a constant drive pressure to send **liquid helium** through the **needle valve, and capillary tube** into **cooling circuit loops.**

5.10.7 After the **LHe** transfer is complete, refill the **LN2 vessel.**

5.10.8 Be sure that the **LHe transfer line** is warmed up and dry before using again, by purging it with warm helium gas.

5.11 LIQUID HELIUM FILLING TO e-BUBBLE CHAMBER AND CENTRAL TUBE

5.11.1 Check the **pressure gauge P2** on the top of **central tube**, to make sure that the pressure in the **e-Bubble chamber** is greater than 15 psig. If it is not, follow the gHe back-filling procedure in step 5.3.5 until the pressure reaches 15 psig.

5.11.2 Maintain the pressure inside the **central tube at** 15 psig by setting **regulator valve 12** at 15 psig, and keeping **valves 9, 11 and 13** open.

5.11.3 Open **ball valve 8**, and insert quickly **LHe transfer line** into **central tube.**

5.11.4 Close **ball valve 16** on the **LHe Dewar.** Remove the plug of **quick connector 14** on the **LHe Dewar**, place the end of the **LHe transfer line** into **quick connector 14** and insert it until it touches **fill valve 15** on the **LHe Dewar.**

5.11.5 Close **globe valve 13, regulator valve 12, needle valves 11 and 9.**

5.11.6 Open **fill valve 15**, insert the **LHe transfer line** to the bottom of **LHe Dewar,** and tighten **quick connector 14.** The boil-off caused by the warm **vacuum jacketed transfer line** being inserted into the **LHe Dewar** will cause immediate pressure rise and transfer liquid helium into the **e-Bubble chamber.** Once the **e-Bubble chamber** is filled with **LHe**, the pressure inside the **central tube** will be gradually over-pressurizing, which prevents air from entering the **central tube.**

5.11.7 Transfer the **liquid helium** at a slow rate, by regulating the pressure in the **LHe Dewar** (in the range 1-2 psig).

5.11.8 Listen for a “rush” of helium gas from the **central tube**, indicating that the LHe has reached the level of the **central fill tube**. Once the **liquid helium transfer** is complete, lift **LHe transfer line** until it just clears **fill valve 15**, then close the **fill valve 15.**

5.11.9 Remove the **LHe transfer line** from the **central tube** and close **ball valve 8.**

5.11.10 Open **ball valve 16** and the **LHe Dewar** is only venting from the **ball valve 16**.

5.11.11 Remove **LHe transfer line** completely from **LHe Dewar,** and plug in **quick connector 14.**

5.11.12 The pressure inside **e-Bubble chamber** is monitored by the **compound pressure/vacuum gauge P2** and is vented out off the **relief valve R6.**

5.12 DURING NORMAL OPERATION

5.12.1 Monitor **temperature sensors** for the holding time of the **liquid helium** and **liquid nitrogen vessels.** The normal boil-off rate of the combined total **liquid helium** volume (about 45 liters) is approximately 500 cc per hour, resulting in a hold time of about 4 days. The **LN_2 vessel** has a net capacity of about 41 liters, and should also last more than 4 days. At end of 4th day, the temperature of the **4K-heat shield** will start to gradually increase above 9K, indicating that the heat load from the **LHe vessel** to the **4K-heat shield** is slowly increasing.

5.13 LOWER TEMPERATURE OF E-BUBBLE CHAMBER

5.13.1 Open **ball valves 3 and 6** on the control panel, this connects the **mechanical pump** to the **pumping port (F1)** of the **cooling circuit loops.**

5.13.2 Plug in the **mechanical pump**, and pump the **cooling circuit loops** to lower the pressure, thereby decreasing the temperature of the **e-Bubble chamber.**

5.13.3 The pumping flow rate is monitored by the **flow meter FM1** on control panel.

5.13.4 Adjust the **helium needle valve operator 105** at the top flange of the cryostat to change the liquid helium mass flow rate entering the **cooling circuit loops** from the **LHe vessel.**

5.13.5 Check **temperature sensors T6, T7 and T8**. When the desired lower temperature has been reached, close **ball valves 3 and 6** on the control panel. Unplug the **mechanical pump.**

5.13.6 Monitor the temperature using the temperature sensors around the **e-Bubble chamber.**

5.14 SYSTEM WARM-UP

5.14.1 System warm-up consists of allowing the cryogen to boil away and the cryostat to warm to room temperature. There are two modes: one is normal warm-up and the other quick warm-up. If the system is left unattended for any length of time during warm-up, Caution signage and taping of the area should be in place beforehand.

5.14.2 Normal warm-up:

5.13.1.1 Open the **helium fill port C1**, open **ball valve 22** on the **helium vent port C2** on the **LHe vessel.**

5.13.1.2 Use **heaters** mounted at the top flange of the **e-Bubble chamber** to increase temperature.

5.13.1.3 Wait for the liquid helium and nitrogen to boil-off and vent out of the pressure relief valves and vent ports.

5.14.3 Quick warm-up:

5.14.3.1 Open **globe valve 13** and set **regulator valve 12** at 5 psig. Connect the **helium gas transfer line** to the connector of **vacuum valve 103** extending from the Cryostat.

5.14.3.2 Open **needle valve 11** and purge the **helium gas transfer line**.

5.14.3.3 Open **vacuum valve 103** and break the vacuum of the **Cryostat vacuum jacket** with warm helium gas from gHe bottle.

5.14.4 After the liquid helium has boiled away and the Cryostat has warmed up to room temperature, be sure that all ports are closed to prevent air from entering the vessel.

5.15 LIQUID WITHDRAWAL

This procedure will normally be used only under exceptional circumstances:

5.14.4.1 Purge the **LHe transfer line** with gaseous helium.

5.14.4.2 Insert the **LHe transfer line** to the bottom of the **LHe vessel** through **helium fill port (C1).**

5.14.4.3 Close **ball valve 16** on the **LHe Dewar.** Remove the plug of **quick connector 14** on the **LHe Dewar**, place the **LHe transfer line** into **quick connector 14** and insert it until it touches **fill ball valve 15** on the **LHe Dewar.**

5.14.4.4 Open **fill valve 15** and insert the **LHe transfer line** to the bottom of the **LHe Dewar.**

5.14.4.5 Tighten **quick connector 14**, open **vent valve 17** on the **LHe Dewar.** Liquid helium transfer from the **LHe vessel** will take place as the helium vapor inside the **LHe vessel** is vented from the **vent valve 17.**

5.14.4.6 When the **LHe** transfer is complete, the temperature measured by **temperature sensor T1** at the bottom of **LHe vessel** will increase abruptly.

5.14.4.7 Wait a few minutes for helium boil-off to settle down, remove **LHe transfer line** until it just clears the **fill valve 15**, and then close the **fill valve 15.** Remove the line completely from the **LHe Dewar.**

5.14.4.8 Close the **vent valve 17**, open **ball valve 16** and let the **LHe Dewar** vent from **ball valve 16.**

5.14.4.9 Install the plug of **quick connector 14** and remove the **LHe transfer line** from **helium fill port (C1).**

5.14.4.10 Seal **helium fill port C1,** close **ball valve 22** on the **helium vent port C2,** to prevent air from entering the **LHe vessel.**

6. Documentation

6.1 EBC Log Book

7. Attachments

7.1 P&ID diagram
7.2 Top flange view
7.3 Flow diagram

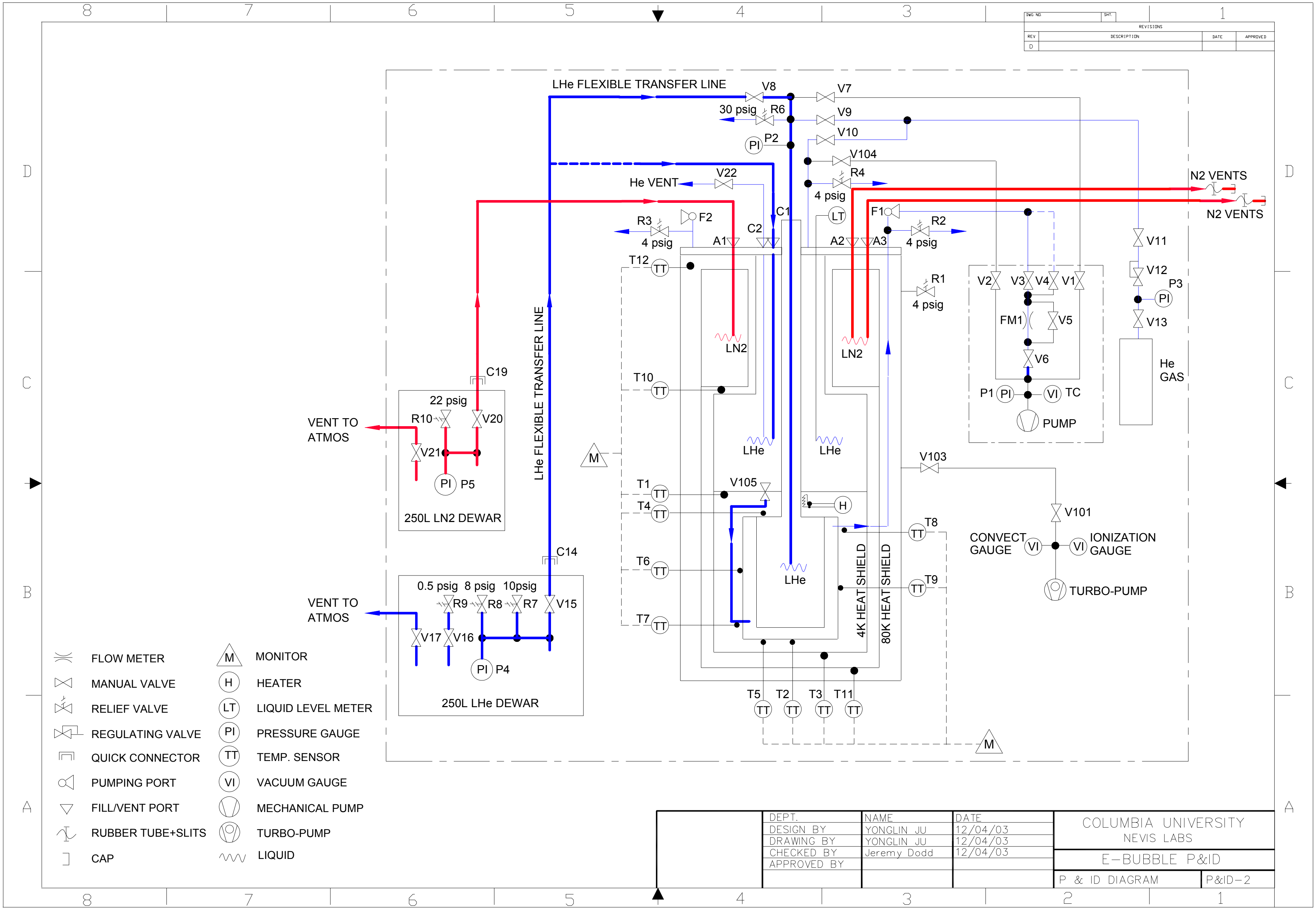


Figure 7.1 P&ID diagram

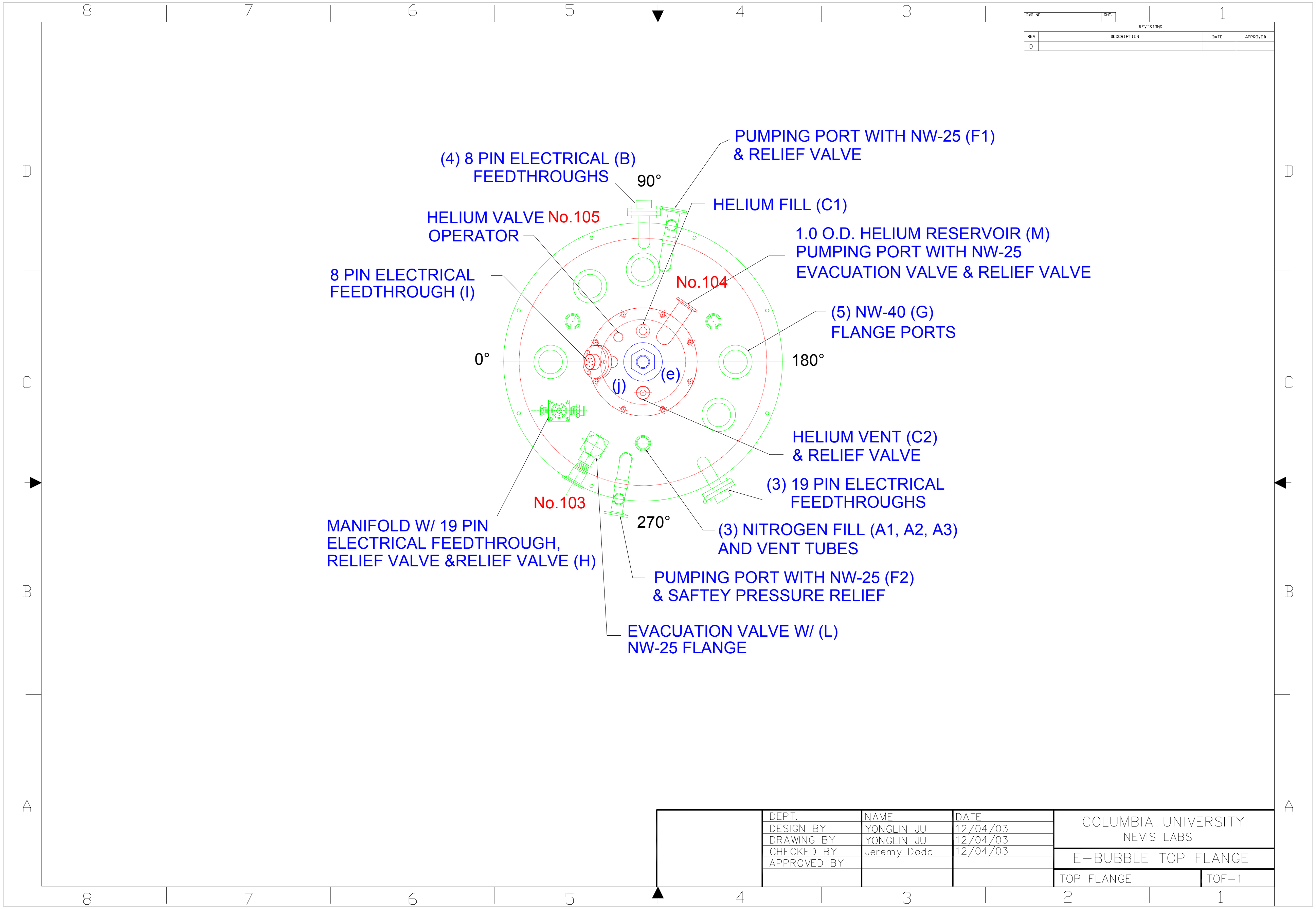


Figure 7.2 Top flange view

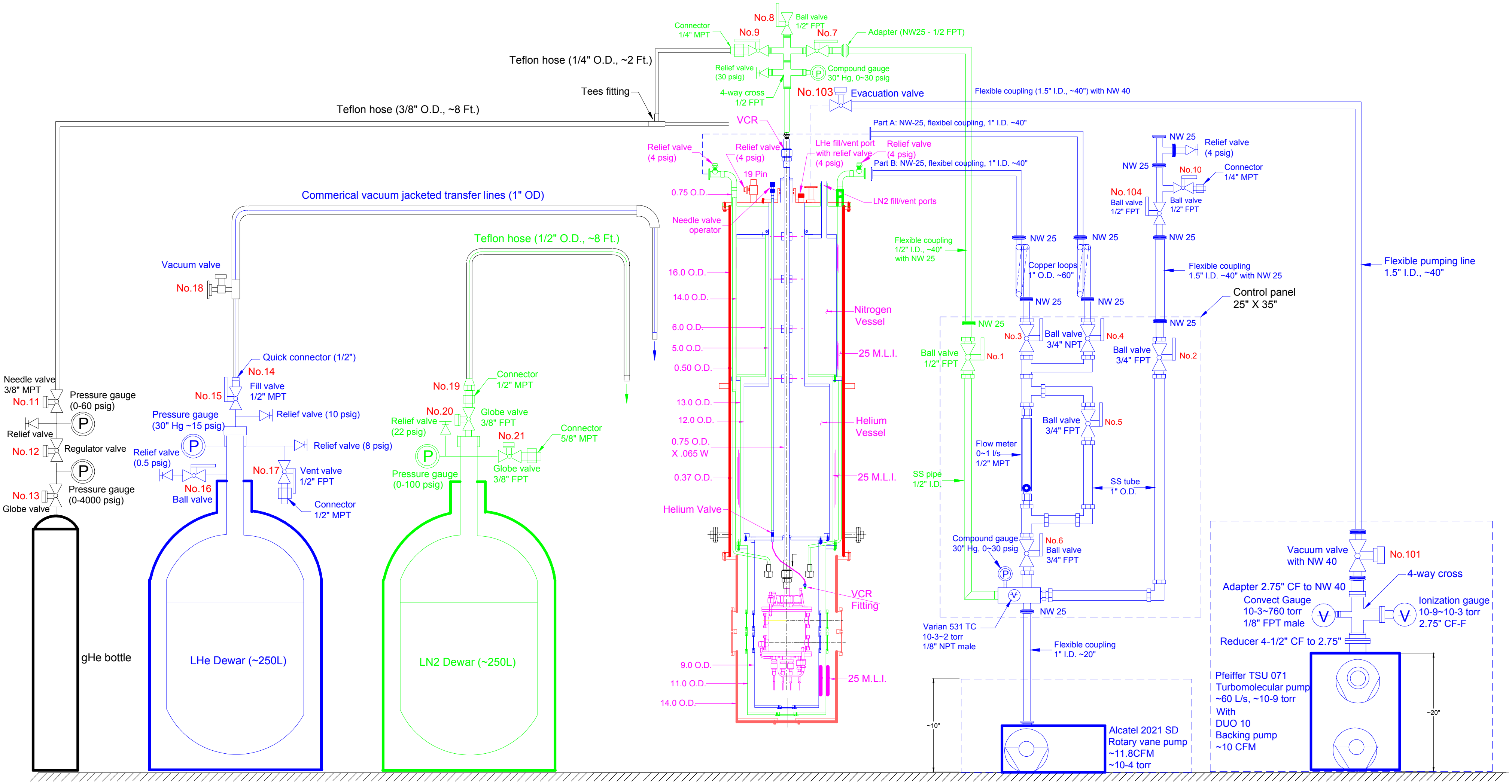


Figure 7.3 Flow diagram

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BROOKHAVEN NATIONAL LABORATORY

Memo

date: *December 17, 2003*

to: *E. Lessard*

from: *J. Durnan*

subject: *LESHC 03-10, Bldg 832, eBubble Cryostat Relief Valve Acceptance Testing*

This Memorandum documents that I have witnessed the testing of Relief Valves R1, R2, R3, R4, R5, and R6 as shown on Columbia University Nevis Labs E-Bubble P&ID-2, as required by the LESHC. The gauge used to perform this testing was a Wallace & Tiernan, Pennwalt Absolute Pressure gauge calibrated by the C-AD Cryo Controls & Instrumentation Group using the MENSOR PCS 400 Pressure Calibration System on December 11, 2003. The testing was done in building 832 on December 12, 2003, by Jeremy Dodd and Yonglin Ju, with the relief valves still attached to the Cryostat. The gas pressure was supplied by a "k" bottle of helium using flex hose to a "T" fitting for mounting the gauge, then flex hose was connected to the Cryostat fittings.
Relief Valve R6, rated for 30 psig, was tested through the Control Panel and the Valve released at 28.8 psig. Relief Valve R1, rated for 4 psig, was tested through Valve 103 and released at 4.0 psig. Relief Valve R2, R3, R4, and R5, all rated 4 psig, were tested through Valve R10. Relief Valves R4 and R5 were tested with needle valve V105 closed then, manually holding Relief Valve R4 down, Relief Valve R5 was tested and released at 4.2 psig and, holding Relief Valve R5 down, R4 released at 4.4 psig. To test Relief Valves R2 and R3, Needle Valve 105 was opened and Relief Valves R4 and R5 were taped down, manually holding Relief Valve R3 down R2 released at 4.5 psig then Relief Valve R2 was held down and R3 released at 5.2 psig. Valves R2 and R3 were difficult to test because of the pressure drop through the Needle Valve 105, we allowed the pressure to stabilize for a reasonable length of time but it is possible that there was still a pressure drop through the needle valve and valves R2 and R3 are set at a lower pressure.

Cc: J. Dodd
J. Ellerkamp
S. Kane
R. Travis